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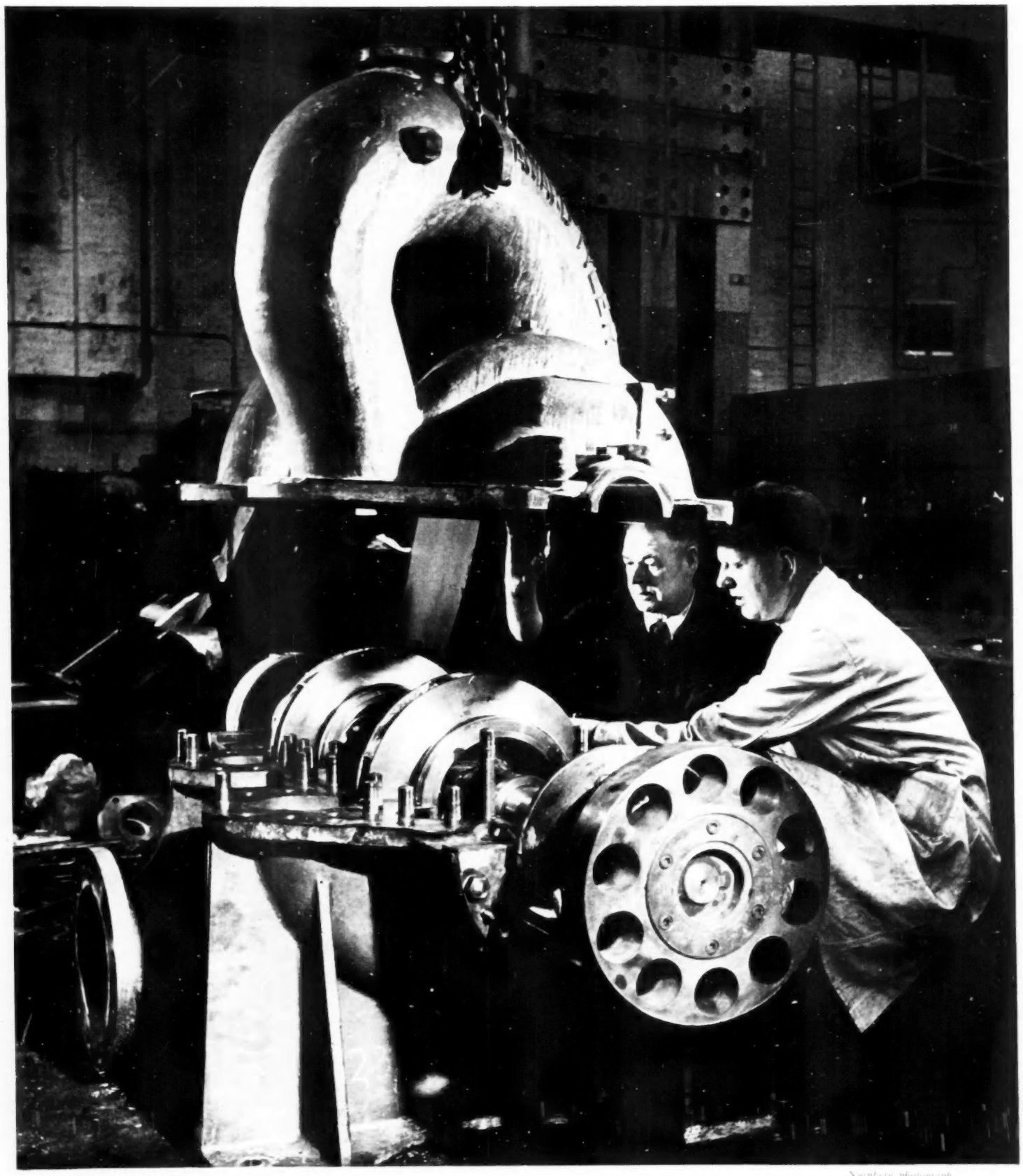

INSPECTING A CARGO PUMP

Nambiere photograph for ENGINEERING

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ENGINEERING

An Illustrated Weekly Journal

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THE PATHFINDERS

As the Farnborough exhibition and flying display come round once again, thoughts turn to the aircraft industry. Its importance as a defence workshop is undisputed; so is its value as aircraft supplier to the British airlines and as an exporter of successful machines. But it is more important even than these two factors would suggest. Its real significance, to all branches of engineering, is that it blazes the trail of technical development. Because the specifications for any kind of aircraft are so exacting, because international competition for airline traffic is so vital to national prestige, and because the ultimate limit of achievement will certainly be beyond the sky, the aircraft industry is continually reaching out into the unknown and accumulating technical knowledge which others can use. When we look around at other branches of engineering and ask what they have contributed to the stock-pot in the past few years, we realise that the aircraft industry, with two or three others, is directly or indirectly responsible for nine-tenths of contemporary engineering development. Its future, therefore, is of paramount interest.

If the future of the industry could be left to the people directly concerned, the rest of us could simply watch its progress from the touch-line. Unfortunately, the industry is so much at the mercy of political and other national forces that some measure of responsibility is shared by many people outside the industry. In his new book, published last week, Sir Roy Fedden analyses the situation and then builds up a synthesised plan for organising its future. His analysis is based on a first-hand appraisal of German experience during the second World War, on the American solution after the war, and on the fundamental importance of adequate and appropriate technical education.

Visiting Germany in 1945 at the head of a Government mission, Sir Roy was deeply impressed by the scale of research staff and facilities. Even at that time there were wind tunnels capable of testing models of aircraft and guided weapons up to speeds of 13,000 m.p.h. Rocket missiles were being put into large-scale production. We had won the war; but only just in time. There had, of course, been some appalling examples of mismanagement in Germany, especially by the high command. But there for the British, the Americans and the Russians to see were some of the most advanced aeronautical establishments and the results of some surprisingly far-seeing research.

The American solution, which Sir Roy holds up as a model of state wisdom, was the appointment by the President, Mr. Truman, of the famous Finletter Commission in 1947. The Commission was given five months to study the current and future needs of American aviation, methods of encouraging developments in the industry, improvements in the Government handling of aeronautical matters, etc. The Commission consisted of five men independent of both the industry and of Government departments. The procedure adopted by the Commission for carrying out this monumental task in such a short time makes fascinating reading, and in Sir Roy's view the proposals put forward by the Commission, speedily implemented by the Government, have paid dividends ever since. "The American aircraft industry at this period was suffering from a number of shortcomings not unlike those which face us to-day. Mr. Truman was wise enough not to attempt to resolve them from within by seeking advice from those who had been responsible for creating the impasse, but set up an entirely independent team to tackle the problem." This kind of approach, he believes, should be adopted forthwith in Britain.

On the question of technical education the changing needs of our times have been widely publicised during the past few years. There is certainly no harm—and there may be much good—in reiterating the urgent need to attract more school leavers into scientific and engineering vocations. There are now many forces hastening this change. The large fund set up by a group of industrial concerns to give grants to non-state schools, so that they can build adequate science laboratories, is typical of the spontaneous action which frequently occurs in this country without waiting for political or Civil Service direction. Quoting some figures from the White Paper on scientific and engineering manpower published last year, Sir Roy says that an analysis of qualified scientists and engineers reveals that there are 1·9 per cent. in aircraft manufacture; 2 per cent. in electrical engineering; 5·2 per cent. in mineral oil refining, and 0·4 per cent. in both the automobile and shipbuilding industries. It should be made clear that these figures are the proportion of qualified scientists and engineers to the total number employed in each industry. A more revealing analysis is obtained by taking the number of qualified scientists and engineers engaged on research and development, and expressing them as a percentage of all the scientists and engineers in each industry. It shows that the aircraft industry leads with 79 per cent., compared with an average of 45 per cent. for all manufacturing industries; 58 per cent. in electrical engineering; 33 per cent. in mineral oil refining; 38 per cent. in the automobile industry; and 9 per cent. in shipbuilding. Some

industries can be charged with having too high a proportion on research and development; others with too low a proportion. The aircraft industry errs on the right side, but the overall pattern of the industry will have changed in the next few years.

Britain's Air Survival, by Sir Roy Fedden. Cassell, London. (11s. 6d.)

* * *

Plain Words

Fifteen members of the House of Commons, constituting the Committee of Public Accounts, examine the manner in which certain public monies are spent and report their findings to the House. Their latest report, published last week, covered several projects of an engineering character, including Government grants towards construction of the Jodrell Bank radio telescope.

In the case of the radio telescope (ENGINEERING, July 12, page 34) the report implies that the consulting engineer in charge was to blame for an increase in cost of £240,000. For example, " It was stated in evidence that the engineering consultant changed the design without the concurrence of the University; new structural features were introduced into the instrument and the complexity and cost were thereby materially increased. Although the University professor, who was primarily responsible for the outline design, lived on the spot, he was not consulted so far as the Department (of Scientific and Industrial Research) were aware." And again, the committee " were particularly surprised to be told that the consulting engineers, before introducing substantial modifications in a novel and costly scientific instrument, had not followed the common-sense course of discussing their plans with the eminent scientist who was in charge of the project. Your Committee regard as highly unsatisfactory a state of affairs in which it was possible for the project to be altered substantially at greatly increased cost without the consent and approval of the Department or of the University or even of discussion with the scientist in charge."

In answer to inquiries by ENGINEERING, the consulting engineer states that both he and the scientist in charge of the project deny that these statements are correct. He emphasises that although the standing orders for the House of Commons provide " that the Committee shall have powers to send for persons, papers and records," no evidence was taken by the committee from the scientist or from himself. The scientist has stated that " no major changes had been introduced without consultation."

The Committee of Public Accounts do a public service in probing into cases of wasteful or careless expenditure, but it would seem to be a matter of elementary justice to allow the individuals or firms likely to be implicated to have their say before a report is published. Further light may yet be thrown on the radio telescope case—a verbatim report of the evidence has still to be published—but in the meantime justice does not appear to have been done.

THE SIGNIFICANCE OF THE I.G.Y. TO ENGINEERS

Geophysics at present is an exploratory science concerned with observing, measuring and attempting to correlate and explain the nature and phenomena of the physical world. Only in a few directions and to limited extents has geophysical discovery passed from the domain of the scientist into that of the engineer. So far, indeed, the trend has been for geophysical science to be assisted by engineering achievement and it is hardly too much to assert that the scope of the current International Geophysical Year is made possible, after a lapse of only 25 years since the Second International Polar Year, largely as the outcome of developments in engineering and instrumentation. Eventually, of course, an accumulation of well-established geophysical knowledge will become available for engineers to apply for the benefit of mankind and the further satisfaction of man's insatiable curiosity. A moment's consideration of what engineering has achieved during the past 200 years on the relatively small scale, restricted to materials and phenomena close to the earth's surface, is enough to excite the imagination at the prospect of what engineers will do during the next two centuries with a third dimension of space becoming increasingly at their disposal.

Some of us may, nevertheless, be tempted to feel that many of the avowed objectives of the I.G.Y. are so purely exploratory as to offer little scope for practical application within the foreseeable future and that, with a leaven of far-sighted engineers among its organisers, the hundred million pounds that the I.G.Y. is estimated to be costing could have been expended more valuably on shorter-term research still within the field of geophysics. Although this is unlikely to represent the majority view of engineers, it will be instructive to consider, however superficially, a few aspects of the present I.G.Y. programme that are of special significance to engineering and kindred applied sciences.

EXPLOITING THE ANTARCTIC

Within each major field of I.G.Y. research certain engineering aspects are exemplified. Least conspicuous is the use to be made, quite as a matter of course, of general-purpose appliances and apparatus developed with no thought of geophysics in mind but which enormously facilitate much of the work and are indispensable to some items in the intended scope of the I.G.Y. This type of engineering contribution includes all normal means of mechanised transport, telecommunication, automatic computation, portable living equipment and domestic supplies, standard scientific instruments, and civil engineering techniques such as surveying and geological prospecting. In addition to availing himself of these fully developed products, the geophysicist has called on the engineer for many special modifications or adaptations of every-day appliances to meet the exceptional conditions to which a number of I.G.Y. observers will be exposed. Some of the best examples of this sort are to be found in the Antarctic establishments where notable engineering features are embodied in the ships that conveyed the expeditions to their bases on the ice fields, in the unloading tackle, the aircraft designed for restricted landing and take-off, the " Weasel " and " Snocat " tractors for transport on uneven ice and in deep snow, the portable crevasse bridges, the prefabricated, insulated buildings, and the plant for heating, ventilation, lighting and drainage. Many recent modifications in all such equipment are experimental and the I.G.Y. affords the first opportunity that has ever occurred for them to be thoroughly tested under polar-service conditions for periods of up to two years. The results obtained will be of great value to designers faced with similar problems in the future should permanent occupation of the Antarctic continent offer feasible commercial prospects.

Much the same significance attaches to what may be termed instrument engineering, connoting the mechanical design and construction of the scientific apparatus regularly used for geophysical and associated research based on astronomy. Under this head may be included a large proportion of the telescopes at permanent observatories, together with their adjustment mechanism, automatic direction-keeping controls, their highly accurate photographic auxiliaries and structural housings. Equally essential to the I.G.Y. are the various national time services, in which engineering and instrument making have contributed to the precision now achieved by the use of atomic caesium frequency standards in addition to vibration-free mountings for quartz resonators in temperature-controlled cellars and an elaborate system of phonic motor indicators, land lines, radio transmission systems and automatic signal recorders and comparators. Astronomical apparatus of special utility for the purposes of the I.G.Y. is exemplified by the photo-zenith tube, the spectro-helioscope, the whole-sky and Markowitz dual-rate moon cameras, the four-colour scanning air-glow recorder, and a variety of spectrographic and photographic equipment including instruments for high-speed cinematography and time-lapse recording of visual phenomena. For several of the newer forms of apparatus and techniques the I.G.Y. offers an unprecedented and unsurpassed opportunity for testing and determining their accuracy against the basic standards of the perceptible universe. At the moment it is difficult to envisage how such experience can be utilised by future engineers in directions other than increasing the precision of geographical navigation and surveying, and by improving the design and construction of highly specialised equipment. Even in this somewhat limited field, however, the demands on engineers—exemplified by the mechanical design and construction of the radio-telescope at Jodrell Bank—are likely to expand indefinitely and to exert a significant influence on technologies at present unforeseen.

UTILISING WEATHER KNOWLEDGE

In contrast with the astronomical aspects of the I.G.Y., the lower-atmospheric meteorological, oceanographical and glaciographical groups of investigations seem to have more engineering significance as regards the application of results than the development of equipment for future research. This is not, of course, to belittle the importance of future research or to suggest that the discoveries during the I.G.Y. will not raise a greater number of new problems than they will solve of the old ones. The practical part to be played by the engineer in such work is suggested by some of the less well-known appliances now coming into use. They include apparatus for wind finding and storm warning by radar, for gravity determinations at the surface and the bottom of the sea, for thermal boring through thick ice, and portable instruments for recording seismic phenomena. Scope for electronic engineers in devising automatic meteorological stations, to provide continuous records for analysis at a few remote central points, is a highly probable future development.

However, the I.G.Y. investigations in the lower atmosphere, the oceans, the earth's crust and the polar ice-caps emphasise less the directions of future research than the knowledge to be gained from co-ordinated world-wide measurements by established meteorological methods, combined with simultaneous solar observations to afford a synoptic picture of cause and effect. Instructive as that picture will be, any possibility of its enabling the world's weather to be controlled, except on a very small local scale, is too remote to warrant consideration. But fuller knowledge of the relations among

variable phenomena above and below the earth's surface, leading to an ability to infer the short-term effects of the observable causes of weather changes, and to forecast long-term trends, should all be of profound significance to engineering in several directions. Greater precision in local weather forecasting, for instance, would permit appreciable economies in concrete construction, space heating, structural design to meet wind and snow loads, and the anticipation of transport obstruction. Some of the long-term consequences are evident from what has already been tentatively done to produce rain by seeding clouds, to promote dew formation, and to utilise the power available in winds, tides, and solar radiation. Even more immediate benefits may be expected in connection with water supply, irrigation and sea-defence schemes, or in determining sea and air transport routes to take the utmost advantage of predominant currents in different ranges of altitude. More detailed gravitational data and seismic knowledge will facilitate the discovery of minerals and methods of winning them. If the investigations were to suggest some means of ascertaining the existence of excessive crustal stresses, or other measurable effects, from which liability to future earthquakes in a particular region could be inferred, structural engineers would develop it eagerly. Even to know the magnitudes and directions of ocean and earth waves emanating from the localities known to be susceptible to earthquakes would mark a valuable advance.

EXTRA-TERRESTRIAL ENGINEERING

In contrast with meteorological research near ground level, exploration through and beyond the atmosphere by rockets and artificial satellites promises results that cannot readily be envisaged as offering much immediate scope for engineering exploitation. Their potential importance to macro-meteorology and radio communication is not, of course, disputed any more than their advancement of pure scientific knowledge can be over-stressed. But the means, as distinct from the observations, of space explorations are very decidedly the concern of engineers who are at present the most essential and active exponents of a new science of experimental celestial mechanics. The combined efforts of the engineer, the chemist, the metallurgist and the aerodynamician have produced, in the modern rocket, the most powerful research apparatus now at the disposal of the geophysical scientist. The magnitude of this contribution, as exemplified by the American "Vanguard" satellite transport rocket, is worth a moment's consideration.

The "Vanguard" finless rocket is about 72 ft. long, 45 in. in maximum diameter, and comprises three separate stage-rockets, each of which is to fall away on burn-out at different pre-designed points in the launching trajectory. In the first stage, powered by a liquid-propellent motor mounted on gimbals, the thrust cylinder is moved by hydraulic actuators permitting a degree of flight path control. The propellent feed pumps are driven by a turbine powered by high-temperature steam produced by the catalytic decomposition of hydrogen peroxide. The propellent fuel—a mixture of petrol, ethyl alcohol and silicon oil—and the liquid oxygen to promote combustion, are in cylindrical tanks maintained under pressure by helium in spherical containers. In the second stage another liquid propellent motor, similarly mounted in gimbals and hydraulically actuated, burns dimethyl high hydrazine, oxidised by nitric acid, both liquids being injected into the combustion chamber by high-pressure helium. The control system includes a three-axis gyroscopic reference equipment of the type in which recent developments permit acceleration and velocity in all planes to be measured, integrated and automatically corrected, such factors as the oblateness and rotational speed of the earth being taken into account. The third stage, fitted with a solid propellent motor and carrying the 20-inch diameter satellite at the base of its nose cone, is mounted on a turntable in the leading end of the second stage so that its trajectory can be stabilised by rotation imparted by secondary tangential rocket units. The actual satellite comprises a gold-plated shell of polished magnesium alloy, weighing some 4½ lb., packed with miniature instruments and radio telemetering equipment, bringing its total all-up weight to about 21 lb. Its designed departure speed, at an altitude of about 300 miles, is nearly 26,000 ft. per second.

By any contemporary standard this is an outstanding work of engineering firmly based, it would seem, on the successful performances already achieved with high-altitude rockets and aircraft automatic-control equipment. The problems inherent in setting a satellite on orbit at the necessary velocity and height are incomparably greater than those entailed in the simpler ephemeral rocket, and it may well be that uncertainty in solving them is responsible for the postponement, from September until early in 1958, of the first launching attempt, and

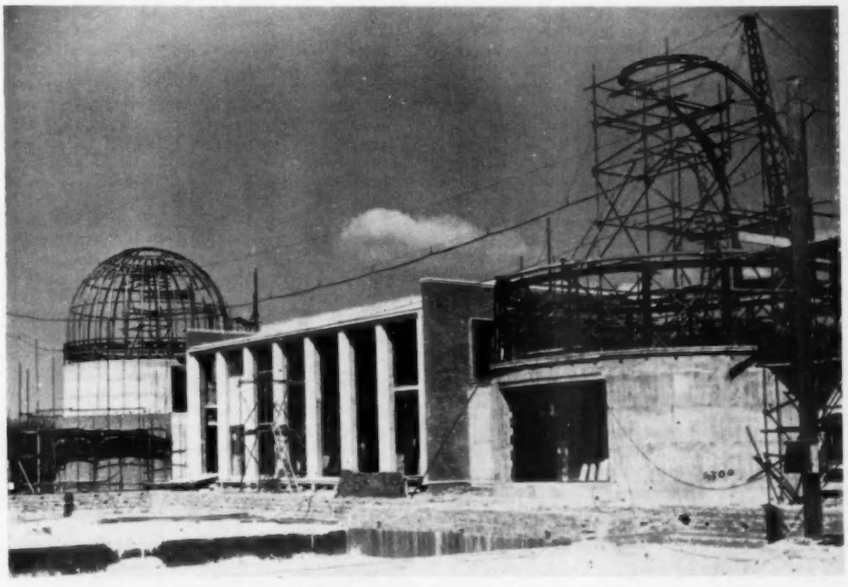

Fig. 1 Northern portion of equatorial group at the Royal Greenwich Observatory, Herstmonceux Castle, Sussex, in the course of construction. The dome on the left will house the 30-in. reflector and that on the right the Yapp 36-in. reflector.

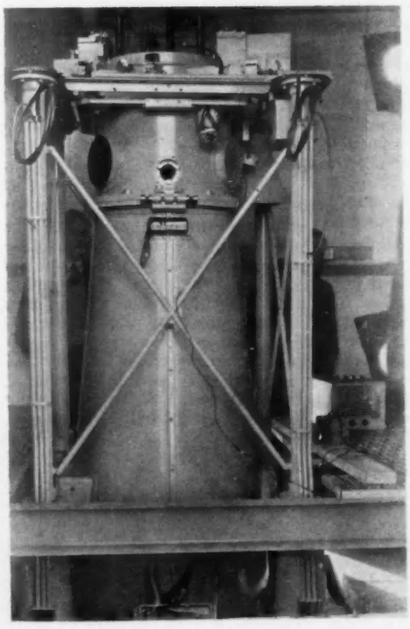

Fig. 2 (left) Photographic-Zenith Tube at the Royal Greenwich Observatory in course of erection.

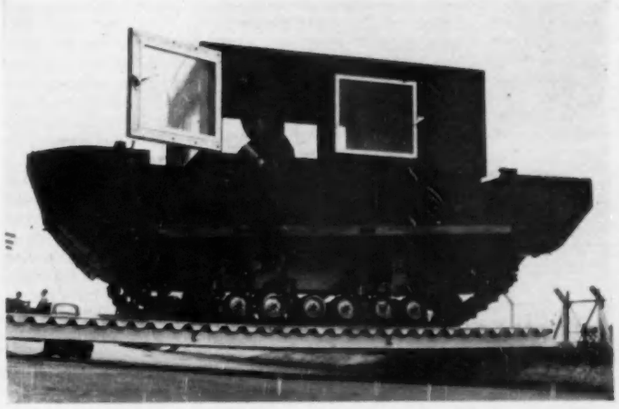

Fig. 3 (right) Portable crevasse bridge built from Noral industrial sheet and sections by the Northern Aluminium Co., Ltd., shown under test by a Weasel tractor at the works of S. Smith and Sons (England), Ltd., Witney.

for the reported proposal to precede it by a trial in November with a smaller 6·4 inch diameter spherical satellite weighing only 4 lb. Equally it may be presumed that the Russian proposal to launch satellites in meridian orbits, thereby losing the advantage of an initial velocity due to the earth's rotation, has not been without some unforeseen difficulties. But the significance to engineering remains: clearly, man's initial attempts to penetrate into outer space by controlled bodies are pre-eminently engineering achievements. Trends of thought during the past fifteen years or so are evidence that such attempts would be made and persisted in until, at the least, a permanent artificial earth satellite becomes a factual achievement. What the I.G.Y. has done in this direction, as in others mentioned earlier, is to give the project an urgency and a purpose, and to provide a wonderful opportunity for organised world-wide observation which so remarkable an experiment needs and deserves.

Notwithstanding reports that Russia has been experimenting with manned rockets, interplanetary travel is likely to remain the material of science fiction for a long time to come. But if the small satellites and the measurements of phenomena by them and by rockets prove to be as successful as is hoped, some of the next steps in extra-terrestrial research can now be foreseen. A bigger satellite, far enough outside the tenuous fringes of the earth's atmosphere for it to remain more or less permanently in orbit, will be the precursor of one or more permanent automatically recording and transmitting stations, robust enough to withstand impacts from small meteorites and energised indefinitely by solar radiation. Even a permanent observatory of this sort landed on the moon, and rockets in trajectories passing beyond and round the moon, capable of returning to earth, are by no means hopelessly speculative conceptions. In terms of geophysical time, the transition from James Watt's kettle to the atomic power station, from Stringfellow's models to the supersonic aircraft, took place overnight !

Here, as elsewhere, the significance of the part to be played by the engineer lies in the conversion of scientific ideas and soundly established theoretical knowledge into practical material structures and machines that work successfully. The problems already envisaged are formidable, as evidenced by the proceedings at the High Altitude and Satellite Rocket Symposium, held at Cranfield last July; but, by the same token, they are already being studied seriously, soberly and competently by people who are at least paving the way towards eventual success. Equally noteworthy, on the experimental side, are the hypersonic and low-density tunnels, the gas guns and high-velocity launching equipment, like those recently developed by the Armament Research and Development Establishment at Fort Halstead, for simulating with reduced scale models the effects of phenomena associated with extremes of speed and altitude.

NEUTRALISING GRAVITY

Not the least significant feature of such work, in this as in other countries, is the methodical effort it is attracting at the very outset of astronautical engineering. The ultimate possibilities are incalculable and too many to enumerate, but one of them must be mentioned because, if it were to become a practical fact, it would revolutionise not only extra-terrestrial transport but also a great deal of present engineering technology. Moreover, some of the observations being conducted during the I.G.Y. are likely to exert an important influence on the development of theoretical studies that, while at present somewhat nebulous for lack of physical data, are nevertheless being seriously considered by a few nuclear scientists. The subject in question has been called electrogravitational propulsion, implying the ability to control and counteract the mutual gravitational force normally and, as far as is now known, universally exerted between all matter independently of whatever medium may be interposed between the attracting masses. It has been verified, for example, that the attraction between the sun and the moon is unaltered by the interposition of the earth during lunar eclipses. It seems not unlikely therefore that the ultimate nature of gravitational attraction resides in the fields of electric force associated with sub-atomic particles. In so far as this is true, there exists the possibility that increasing knowledge of the agents and mechanism of gravitation and of the magnetic fields associated with rotating bodies by virtue of their rotation, may one day permit local gravitation to be electrically neutralised.

In the present state of knowledge of nuclear- and geo-physics, electro-gravitational control is rather a concept than a theory, and its practical realisation is remote. It exemplifies, nevertheless, one among many aspects of the I.G.Y. that are of significance to engineering because, sooner or later, they will lead to radical changes in practice just as nuclear physics is now modifying the design of power stations and prime movers. The rapidity with which these developments have come about is clear indication that engineers will lose nothing and may gain much by studying the more severely scientific work of the I.G.Y. and exercising their imaginations on it. More immediately, as has been suggested in the foregoing survey, the results of the I.G.Y. ought to promote engineering progress in three wide fields: the exploitation of inclement climatic regions, especially the polar continents; the utilisation of weather phenomena and solar radiation; and the development of experimental equipment for extra-terrestrial research. Such progress will not be as rapid or as rewarding as it might be unless engineers and their colleagues in related scientific practice take an active part in constructive thought about the potentialities of geophysical discoveries, which are virtually certain to reveal, on the one hand projects that engineers already know how to undertake if the idea of doing so occurs to them; and, on the other, projects that are obviously worth while if engineers can devise how to achieve them on a commercially successful basis. The engineer owes it to posterity to foresee the possibilities of the I.G.Y. and to anticipate the results of continued and extending geophysical research. His duty in these directions will be the more compelling if, as may be hoped, the present temporary effort of the I.G.Y. leads to the establishment of permanent geophysical research on an international scale.

Letters to the Editor

MANAGEMENT AND BAD WRITING

SIR, Surely the authors of "Management is Hampered by Bad Technical Writing," in your issue of August 2, page 137, must live in the most fragile of glasshouses. They use too many long words. The lilting rhythm of the Civil Service weaves its Lorelei spell as early as the second paragraph. "Remuneration" instead of "pay"; "those engaged in this . . . activity" instead of "those who do this work."

The fourth paragraph with its enchanting trochaic metre is almost pure poetry, but it wouldn't do for my foremen. If I don't give my men clear orders, they will muck things up. They understand direct and vulgar words like "muck up" better than "disastrous consequences." This paragraph, by the way, takes one hundred and thirty-two words to state the obvious.

Yours faithfully,
A. BATTERSBY.

8 Cranbourne-drive,
Pinner,
Middlesex.
August 12, 1957.

★ ★ ★

THE BIGGER THE ORGANISATION

SIR, I have just read the leading article, on page 33 of your issue of July 12, with interest but also some surprise. Surely the explanation of the size effect in industrial organisations, the results of which in respect of strikes, absenteeism and accidents have been noted by Professor R. W. Revans, is not obscure? It should be obvious to anyone who has worked in both large and small organisations, and who has given any serious thought to the matter. The explanation lies, of course, in a failure to achieve, in the larger organisations, satisfactory human relationships.

A small and relatively independent organisation must be managed with reasonable competence if it is to survive at all; and, being small, it can, and usually will, be so managed by a single individual, who would not remain long in control unless he was sufficiently competent. A major part of the problem confronting this individual will be to establish and maintain satisfactory human relationships in the organisation he is controlling, and he will have little chance of avoiding or skimping this essential part of his job. But he will be greatly helped by the fact that he will usually have a fairly free hand in the selection, promotion, dismissal and general treatment of the staff and employees concerned. In brief, he will usually possess adequate means to produce the desired result, in other words a reasonably happy and efficient industrial team; something that is impossible without satisfactory human relationships.

Contrast this position with that of the man in charge of an equal number of staff and employees who form only a section of a much larger organisation. Firstly, this individual, once he has attained to such a position, is unlikely to have to depend to anything like the same extent on remaining competent to hold it. If the results he achieves become too noticeably bad, at the worst he may suffer transfer to a similar position elsewhere; but, if the organisation is really large, he may even be promoted, since this may be the only way by which his suffering colleagues or immediate superiors may be able to disembarrass themselves of his services.

Secondly, this individual will probably have a strictly limited say in the selection, promotion, dismissal and general treatment of the staff and employees under his control, and it will not be surprising if he finds it very difficult, or even impossible, to weld them into any sort of team at all. And, since all, or most, of the sections of large organisations tend automatically towards his state, human relationships cannot be satisfactory and the inevitable results follow.

Solving this problem of attaining satisfactory human relationships in large industrial organisations is certainly as important as solving other industrial problems, such as those posed by automation, but the problem itself requires to be more clearly stated and more widely recognised than it is at present. Here, the work of Professor Revans and others in this field should help, and it is to be hoped that, by the time possible solutions to this problem begin to emerge from the results of such work, the climate of industrial opinion will have become more favourable to their trial.

Yours faithfully,
H. W. S. MARSHALL.

P.O. Box 1,
Kirkuk,
Iraq.
August 6, 1957.

Letters to the Editor (continued)

BRITAIN AND EURATOM

SIR, With reference to the Weekly Survey note in your issue of August 2, entitled "Britain and Euratom," I would like to offer a brief comment on the final paragraph, where it is said that "the most valid objection raised so far to complete British membership to Euratom concerns defence. The surrender of sovereignty involved in the control of fissile materials and the right of Euratom's controlling inspectors to visit every factory using them, would be difficult to swallow." I do not think that this is quite accurate. Paragraph 3 of Article 84 in Chapter VII, "Security Control," of the Euratom Treaty states:—

"The control (i.e. of Euratom's inspectors) cannot extend to materials destined for the needs of defence which are in course of special preparation for these needs, or which, after this preparation are—in conformity with a plan of operations—installed or stocked in a military establishment."

Even as a member of Euratom, therefore, Britain would retain control of her own defence programme. I rather wonder if this "most valid objection" to Britain's membership of Euratom consequently disappears.

Yours faithfully,
ROY PRYCE,
Information Officer.

U.K. Delegation of E.C.S.C.,
23 Chesham-street,
London, S.W.1.
August 14, 1957.

★ ★ ★

ON THE PLATFORM

SIR,

The porters down at Basingstoke
Indulge in late night dancing (folk)
(What sort of dance do porters do ?
Would it be "Everybody change at Crewe"?)
A correspondent with shocked eyes
Surveyed the scene with wild surmise.
He thought such things so anti-laugh
He wrote the *Daily Telegraph*
To ask why Basingstoke—its station—
Was influenced so by nationalisation
That B.R. porters—saucy devils—
Indulge in terpsichorean revels.
I like, Sir, your reply so coy,
The State breeds not spontaneous joy.

Yours, etc.,
F.H.S.

August 17, 1957.

(F.H.S. is referring to the Human Element, Aug. 16.)

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MR. V. J. F. BRAIN

A Leading Australian Electrical Engineer

News has reached us of the death in Australia on June 11 of Mr. Vivian James Foxton Brain, chairman of the Electricity Authority of New South Wales and vice-chairman of the Electricity Commission of New South Wales. Mr. Brain, who was 60 years of age, was born at Wollongong, N.S.W., and educated at Sydney Grammar School. He later graduated with first class honours in electrical engineering at Sydney University and after service in France with the Royal Australian Engineers during the war of 1914-18, spent 7 years in the United States with the American General Electric Company and other firms. On his return, Mr. Brain was appointed chief electrical engineer of the N.S.W. Department of Public Works. In 1946 he was made chairman of the Electricity Authority, and in 1950 vice-chairman of the Electricity Commission of New South Wales.

A member of the Institution of Engineers, Australia, for many years, Mr. Brain served as President in 1951. He was also oversea representative of the Institution of Electrical Engineers, London, and the local honorary secretary of the American Institute of Electrical Engineers.

THE 21ST ENGINEERING EXHIBITION

THINGS TO SEE, THINGS TO THINK ABOUT

When the Engineering Exhibition opens at Olympia—London's largest indoor exhibition site—on August 29, nuclear energy will be covered for the first time in the history of this long-established show. The full title is the Engineering, Marine, Welding and Nuclear Energy Exhibition.

The official opening will be performed by Sir Christopher Hinton, F.R.S., who has directed the Industrial Group of the United Kingdom Atomic Energy Authority in its first fruitful years. Sir Christopher has recently been appointed chairman of the Central Electricity Generating Board. Stands showing exhibits in this relatively new branch of engineering will carry a special plaque with the caption "British Nuclear Energy Equipment."

The first Engineering and Marine Exhibition was held in 1906 with the support of 100 exhibitors. There will be over 500 exhibitors this year. The marine element is still strong and, in addition to nuclear energy, welding equipment forms a separate section. Mr. W. K. G. Allen, president of the British Engineers Association, is this year's president of the Exhibition, which is sponsored by six associations and organised by F. W. Bridges and Sons, Limited.

Engines—particularly Diesel engines—will be well represented. The newer forms of prime mover—gas-turbines and free-piston gasifiers—will attract keen interest. The Royal Navy is expected to show some frigate machinery. In heavy engineering there will also be railway locomotives and equipment. Among novel and unusual exhibits there will be disc brakes, a jelly for removing scale from beams or plates, a mechanism for discouraging the growth of barnacles on ships' hulls, a self-contained oxygen generating plant, a model of the Jodrell Bank radio-telescope, stud-welding guns, creep correctors (to prevent movement of long cylinders during welding), a photo-electric tracer for gas cutting plant, a model of a ship with nuclear propulsion machinery, "canned" pumps for use in atomic plants, and glass that offers protection against radiation.

A preliminary examination of the products to be shown indicates that they can be classified under more than a thousand headings. A special guide to the Exhibition will be published in ENGINEERING next week and there will be special articles in that and subsequent issues, dealing with things to see at Olympia, and things to think about on the advancing frontiers of engineering. The exhibition opens daily except Sunday from 10 a.m. to 6 p.m. (Fridays 8 p.m.) until September 12. ENGINEERING has had a stand at every exhibition from the first; this year it is stand 8F on the ground floor of the Grand Hall.

Obituary

MR. ATHOLL BLAIR

Builder of Marine Engines

Dr. J. Cameron Smail, O.B.E., F.R.S.E., Principal Emeritus of Heriot Watt College, Edinburgh, writes:

The unexpected death of Atholl Blair, C.B.E., M.Sc., F.C.G.I., M.I.Mech.E., in Belfast on August 12 at the age of 71 removes a mechanical engineer of outstanding ability and distinction, who was associated with the firm of Harland and Wolff for 50 years. He retired from the position of manager of the engine works and a director of the firm about four years ago, being retained in a consultative capacity. In presenting him for the honorary degree of M.Sc. of Queen's University, Belfast, a month ago, Professor Warnock said that Mr. Blair was probably responsible for building a greater aggregate and variety of marine propelling machinery than any other man. His steam engines, turbines and Diesel engines are to be found the world over.

Atholl Blair was the second son of the late Sir Robert Blair, a distinguished educationist, and he was educated at George Watson's Boys College, Edinburgh, and St. Andrew's School, Dublin. He pursued his engineering training at the City and Guilds College, London, where he came under the influence of Professor W. E. Dalby. He was apprenticed to Harland and Wolff, the firm with which he continued until his retirement.

It is impossible to chronicle the vast output and variety of this firm's operations in the course of 50 years, and there are few examples of an engineer being so continuously associated with a great and expanding organisation of world-wide repute over such a long period. His great capacity for hard work, his integrity, and wide outlook enabled him to keep pace with modern developments, and his human touch secured such relations of good will with the work-people as were abundantly evident on his retirement. Under his direction came many young men whose careers were influenced by his interest and guidance, and many now hold important engineering positions.

Technical education was one of his many interests—the present distinguished Principal of the Belfast Technical College was one of his protégés—and he did much to assist the recent developments of mechanical and electrical engineering, jointly sponsored by the University and the Belfast Corporation, for considerable expansion in buildings and equipment. Recently, he brought forward proposals for easing the very difficult problems of transport in Belfast by schemes for additional bridges on the Lagan, schemes which are still under consideration.

In the complicated region of relations between employers and employed, his wide experience and exceptional knowledge of working conditions were frequently called upon, and he was a member of many industrial committees. He was personally endowed with considerable mechanical skill and artistic feeling, which found expression in the construction of models, sketching and painting.

Recognition of his work came by the award of the M.B.E., followed later by the C.B.E. His old College conferred its Fellowship upon him, he was an honorary member (and past president) of the Belfast Association of Engineers, and Belfast University made him an Honorary M.Sc., but probably the best unexpressed recognition of his personality remains in the hearts of the Belfast workers of Harland and Wolff.

Weekly Survey

Cover Picture. *Centrifugal pumps such as the one shown in the illustration are used on large tankers to handle the cargo. Their capacities may be as large as 1,500 tons per hour and they may be driven by steam turbines or electric motors. The one shown is a two-stage machine.*

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English Tornadoes

The Englishman at times may envy the material prosperity of his American counterpart but climatically he prefers the reasonable weather of England to the tornadoes which beset the United States, where in 1949 no less than 290 were recorded. He may think notionally with a kind eye to the song-hit of the 1920's, " Yes, we have no tornadoes! " and think wrongly. Mr. H. H. Lamb, in Geophysical Memoir 99, *Tornadoes in England, May* 21, 1950, discloses that the area worst affected in Britain by tornadoes is the lower Thames Valley and the Chiltern Hills. This area has a frequency rate of 0·5 destructive tornadoes per 10,000 sq. km. (3,860 sq. miles) per annum, compared with 0·56 for the worst afflicted American states of Kansas and Iowa. Parts of these states, of course, suffer a much higher rate, and the damage may exceed £300,000 for each of the few very severe strikes.

The tornadoes of Britain are largely confined to south-east and central England south of the Mersey-Wash line, with a secondary pocket in Yorkshire. Their distribution, as would be expected, is not dissimilar from the distribution of thunder days, for which the peak is concentrated south of the Wash. The vast energy of a tornado with its wind whirls reaching momentary wind speeds of 200 m.p.h. is associated with the development of a vortex, horizontal in the upper atmosphere and bending to the ground at one end, to act like an enormous centrifugal pump and to look like a great marching palm tree. Thus, in 1950, damage amounting to £50,000 was wrought along a track of 65 miles—one of Europe's longest—from south of Wendover, Bucks, to the Fens near Ely. At Wendover a 50 yard wide strip of large elms was battered flat, house roofs were lifted and six minutes later at Halton the " thing " raised the heavy roof of the power station. Later a duck pond was sucked into a ten foot water column and carried forward in the narrow vortex. The main blow fell upon Linslade, Bucks, where wind and suction carried objects half a mile and threw down with the rain and lightning two-inch hailstones, some in six-inch clusters. Northward, and two hours later, at Sutton, Cambridge, trees a yard in diameter were twisted off and a double-decker bus overturned before the tornado disappeared over the North Sea.

Fortunately the tornado path is intensely narrow, a yard to a few hundred yards wide, and cannot be compared with the more disastrous and more extensive typhoons and hurricanes of the tropics. Yet what would have happened if a slender suspension bridge had lain in the path of the 1950 tornado is of interest to bridge designers. In English tornado history none is recorded for the counties of Cheshire, Staffordshire, Leicestershire or Suffolk. Are they to remain immune and will the recent increase in the tornado rate continue?

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Anti-Corrosion Week

A Corrosion Exhibition to be held at the Royal Horticultural Society's Old Hall, Vincent-square, London, S.W.1, from October 15 to 17 is to be one of the principal events of a National Anti-Corrosion Week. The Parliamentary Secretary to the Ministry of Works, Mr. Harmar Nicholls, M.P., has accepted an invitation to open the exhibition officially on the first day. The exhibits, displayed by 54 firms, will be concerned with anti-corrosion equipment, products and services.

The National Anti-Corrosion Week has been organised and sponsored by the Leonard Hill Technical Group, publishers of the monthly journal *Corrosion Technology*, with the support of technical and engineering associations. In addition to the exhibition, a Corrosion Convention will meet at the Central Hall, London, S.W.1, on October 15 and 16, when twelve papers covering a wide range of subjects from paints to cathodic protection, and dealing also with the special problems of the shipping, chemical, oil and other industries, will be presented and discussed. The main purpose of the Week is to encourage the greater use of anti-corrosion products and corrosion-resistant materials and so reduce industry's heavy losses due to corrosion. Inquiries should be addressed to the organisers, at Stratford House, 9 Eden-street, London, N.W.1.

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Staffing the C.E.A.

The news that Sir Christopher Hinton had agreed to become the head of the new Central Electricity Generating Board of the C.E.A. has been well received. For some months now—since the Government decided in the spring to exercise a much closer control of the nationalised industries—there has been a tendency to discount the likelihood of first-class men joining any of them. The departures of Sir Miles Thomas from B.O.A.C. and Peter Masefield from B.E.A. underlined the feeling that there was really very little a good man could do but bow to the dictates of official expediency. The abortive attempt to restrain prices, which began with coal, gas, electricity and public transport, showed quite clearly that the Government were prepared to be tough where they could be so with impunity, i.e., with the Boards. The illusion which anyone might still have entertained—that the B.T.C., for example, or the C.E.A.—were operating on commercial lines and bearing the full responsibility of profit and loss was quickly dispatched.

It now remains to be seen how far appointments to the public boards will be political ones. Sir Christopher Hinton's acceptance of the post is no lead in either direction, for he was, as head of the Industrial Group of the Atomic Energy Authority, already under the control of a Government department, the new Ministry of Power, and had been responsible to the Minister of Supply before that. Also, Sir Christopher's career is more that of the Civil Servant than of the high-powered industrialist or trade union official. There was a strong case for offering him the job, since his experience in A.E.A. will make an invaluable contribution to the C.E.A.'s knowledge at the beginning of the atomic era. He was, therefore, a " technical " appointment, of the highest order. What of the other members of the Board who will shortly retire ?

Lord Citrine is due to go shortly. The impact of his strong personality upon the development of electricity production has been considerable. Some say, probably rightly, that no Minister would for long oppose him and that the C.E.A. therefore escaped most of the " squeezes " of recent years—financial and political. The appointment of his successor will test the resourcefulness of Mr. Macmillan and Lord Mills; the depreciation of the value of salaries (however high) will not help them.

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London Transport Uneasy

Judged by comparison with the British Transport Commission as a whole, London Transport is a profitable undertaking. Yet the net revenue surplus of £4·5 million for 1956 fell short by about £1 million of the amount required to meet London Transport's share of the annual interest on capital and other central costs of the B.T.C. The report " London Transport in 1956 " brings out the essential dilemma facing the London Transport Executive, namely a decline of 4·4 per cent. in the total number of passengers carried, with no relief during the rush-hour period. The drop in traffic occurred entirely on the bus and coach services and outside the peak periods. On the underground there was some increase in traffic.

The report attributes the decline to the growth of private motoring and to television. It points out that the number of private cars in London increased by 16 per cent. in 1955 and 10 per cent. in 1956 and it estimates that nearly half the net fall in passenger miles can be attributed to this growth. The frightening prospect is held out of a further doubling in the number of private cars over the next eight years. The process is cumulative because, as a result of the growing congestion on the streets, the bus services become less regular and more and more people decide to acquire their own transport. The Suez crisis, it is pointed out, provided full justification for London Transport's claim to be able to handle a greatly increased number of passengers provided traffic congestion is reduced.

The report claims that unless steps are taken to reduce congestion and to stagger rush-hour travel there are only two alternatives: a great network of new rail and road facilities which would entail prohibitive cost, or a serious increase in overcrowding. Neither of these would appear to provide a practicable solution of the problem.

There were, however, some favourable factors during the past year. In addition to the increase in the number of passengers due to petrol rationing there was an improvement in regularity of service due to an easement of staff shortage. There were also more people in employment in the London Transport area, and although this increased rush-hour problems it prevented a further fall in the number of passengers carried.

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Heavy Engineering Star

The spread of the John Brown group over a wide field of engineering during the past decade is as good an example as can be found of diversification on the part of an old-established shipbuilding concern. The report of the company's chairman, Lord Aberconway, presented at their 93rd annual general meeting provides a most interesting account of the group's spread and of recent developments. Overall they have had a good year, with trading profits up from £2·96 million (after depreciation) last year to £3·13 million. The amount set aside for depreciation was also greater, £759,000 compared with £674,000.

Since the war John Brown have gradually edged themselved into industrial markets and are now considerably less dependent on marine business than they were. Yet their shipyard and engine works are fully employed and booked far ahead. In Lord Aberconway's words, " Orders on hand for ships of a wide variety of types will keep the shipyard busy for many years to come." Of all fields in the metal-using industries of the world there is none so besieged with unsatisfied demand as the shipyards. Expansion in the land boiler field has been most successful; John Brown Land Boilers Limited are now engaged " upon a large programme of construction." The acquisition of Costain-John Brown, formerly jointly owned with Richard Costain, is the logical development of the entry into the power-station field with land boilers, providing the group with first-class constructional engineering facilities. For the present, however, the company are engaged on important contracts for the oil and chemical industries.

The acquisition of Westland Aircraft has brought the group into a field—helicopters—

where there should be considerable developments during the next decade. Machine tools, power tools and engineers' cutting tools, coalmining plant, railway carriages and wagons, and other general engineering products complete a range which places the group in a position of suppliers to the oil, chemical, transport (air, land and sea) and engineering industries—a base as wide and varied as that of any manufacturing company to-day.

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France and the Common Market

The partial devaluation of the franc by 20 per cent. will in the short run considerably improve the prospects of French industry in the European Common Market. There are still, however, a number of uncertainties regarding the future of European exchange rates and it is expected that these will be dealt with at the next meeting of the International Monetary Fund in September. There is, for example, much discussion of the need for an upward valuation of the mark since the strong demand for the German currency was one of the factors tending to weaken the franc and continues to exert pressure on sterling. It is, moreover, unlikely that the other countries forming the European Common Market will be satisfied in the long run to accept the present arrangements under which French manufacturers receive a 20 per cent. export subsidy and imports into France, other than raw materials, are restricted by a special duty of 20 per cent. They may well insist on a full devaluation of the franc before the Common Market Treaty is implemented.

The French balance of payments crisis arises largely from the rapid expansion in industrial production over the last few years. Owing to the shortage of indigenous raw materials this brought about a sharp rise in imports of raw materials, which now account for about 40 per cent. of total French imports, without a corresponding rise in exports. The present expedient was adopted, in preference to complete devaluation, in an attempt to avoid a sharp rise in prices of raw materials and hence in industrial costs. The success of the measure will depend on whether French industrial output can be further expanded without creating a situation of over full employment, since if prices on the home market do not rise there will be no reduction in home demand to free additional goods for export.

Apart from the aircraft industry, in which France is the strongest of the six common market countries, the French engineering industry has hitherto been in a very weak position, *vis-à-vis* competitors. Although the export subsidy is expected to bring French export prices into line, the French mechanical engineering industry is much more dependent on imports of raw materials then either the German or Belgian industries, and French marketing organisations are weaker.

Some French manufacturers are also worried about the growth of United States subsidiary companies in other common market countries. For example, American investment in Italian industry has grown from 39 million dols. in 1955 to 55·7 million dols. in 1956 and is expected to be still higher this year. It is difficult to escape the conclusion that the partial devaluation of the French currency will fail to achieve its objects because it does not face up to the real root of the country's difficulties, namely the need to reduce the present standard of living in order to improve future competitive strength.

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More Pumps and Compressors

During the last ten years the output of Worthington-Simpson Limited, Newark, makers of condensers, pumps and compressors, and special machinery "to order," has trebled in terms of units manufactured. In terms of turnover it has increased between three- and four-fold because some of the units manufactured have been on a large scale as a result of a series of large contracts—for example, the entire condensing, feed heating and de-aerating plant at several of the Central Electricity Authority's new power stations, among them Stayhorpe A, Drakelow A and Hams Hall C. Although, at present, atomic energy applications affect a comparatively small proportion of their business, the company foresees tremendous opportunities in this field for pumping and condensing machinery, and particularly for themselves in atomic marine propulsion, since they are already well established in the marine world and they have at their disposal the experience of their American associate company who were responsible for the pumps on the submarines Nautilus and Sea Wolf. In addition to these new applications, the increasing use of pneumatics in industry generally is likely to be reflected in increasing sales of "off-the-peg" compressors.

Worthington-Simpson have therefore been facing the problem of increasing their output. Being located on the outskirts of a country town, and not in the heart of an industrial area, the possibility of increasing their labour force to any large extent is limited. Instead, they are ploughing back much of their profits into improving their existing facilities so as to increase productivity substantially with their existing labour force.

For several years now the company have been re-equipping with advanced machine tools, automatic arc welding equipment, and shell-moulding plant (this latter being increasingly used, with great economic advantage, for producing castings for their smaller pumps and compressors). They have installed a temperature-controlled standards room, and their metallurgical laboratories and materials test department are soon to be extended and modernised. A new foundry will have shakeouts, dust collectors, and sandmills, and will conform with the new Act which requires the suppression at source of dust and fumes. The boundaries of the works are being pushed out to allow for further rationalisation of their old-established shops, and currently a new fitting shop is being built where it is intended to set up flow-line production of their new range of rotary compressors, for heavy industrial use. Elsewhere in this issue will be found a description of the new compressors.

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Civil Engineering and the Oil Industry

In addition to being one of the principal factors contributing to the world-wide shipbuilding boom, the increasing demand for oil is providing a substantial volume of work for the civil engineering and contracting industries throughout the world. An example is provided by last week's announcement that Shell Petroleum are to complete in the next two years a new deepwater tanker terminal at Punta Gorda, on the entrance to Lake Maracaibo, at a cost of £30 million. The initial capacity of the terminal is to be 35 million tons of crude oil per annum and storage equipment is to be provided for 4 million barrels.

The Kuwait Oil Company has also released further details of its plans for a second oil jetty at Kuwait which is to be built over the next two years at a cost of about £8 million. This jetty is designed to accommodate supertankers up to 100,000 tons d.w., of which it will be possible to berth three at the same time. The average loading rate will be 5,000 tons an hour with a maximum rate of 6,750 tons an hour.

In this country, preliminary work began earlier this month at the British Petroleum Company's site for a crude-oil tanker terminal at a point on the south shore of Milford Haven and etnders have been invited for the construction of the jetty. The berth will have a depth at low water of nearly 55 ft. and will thus be able to receive the largest tankers. The actual construction of the jetty is expected to start in the spring of 1958.

On the oposite shore of Milford Haven the Esso Petroleum Company is still awaiting planning permission from the Ministry of Housing and Local Government for the erection of a new refinery and oil tanker terminal, of which the combined cost is estimated at about £20 million.

When completed in 1960, the initial capacity of the plant will be 5½ million tons of crude oil per annum. These developments, however, represent only a small fraction of the amount of new constructional work which will be required on oil berths and jetties before the large supertankers can be brought into general service in this country.

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Trading with China

The August issue of the "China Trade and Economic Newsletter" sets out a number of reasons why the relaxation of the embargo on exports to China is unlikely to result in "an immediate and dramatic" effect on current Chinese purchases from this country. Apart from the inherent rigidity of a planned economy it is pointed out that orders have probably already been placed for a large part of the imports required in 1958 and the early part of 1959.

Good prospects are, however, foreseen for the later part of 1959 and for subsequent years provided British exporters start immediately to lay the groundwork for such an expansion of trade. The scope for the expansion of British exports is shown by the fact that China is already importing machinery and industrial equipment to the value of £400 to £450 million, but the British share of these imports is negligible, averaging under £1 million per annum.

Anxiety has been expressed from time to time regarding China's ability to pay for greatly expanded imports from this country. Sir David Eccles, however, stated in May that China's exports to the sterling area, mainly to Hong Kong and Malaya, have been exceeding her imports from the sterling area by between £40 million and £70 million per annum. During the current year this favourable balance has been running at a record level and may exceed £100 million for the whole of 1957.

Although the Chinese machine tool industry is said to have expanded production fourfold since 1952, and present capacity is claimed to be sufficient to meet about 60 per cent. of the country's needs, there are good prospects for the export from this country of the more complex and high-precision types of machine tool. The latest statistics covering the British machine tool industry show that as a result of declining home demand and an increased rate of delivery, the backlog of orders has fallen from some 16 months output in June, 1956, to about 11 months output in May, 1957. As a result of the better delivery position export orders rose from £9·2 millions in the first five months of 1956 to £11·4 million in the corresponding period of 1957. The machine tool industry would thus appear to be well placed to take advantage of increased orders from China.

A relatively slow development of exports to China may well prove in the best interests of British exporters. There are prospects of good increases in total exports to the United States and Australia—at present this country's most important export markets—and considerable difficulty might be experienced in meeting a big demand from China over the next twelve months. As things are there should be ample time to plan for an expansion in exports to China provided the necessary preliminary steps are taken now.

EXPANDING AIR TRAFFIC

Air traffic, it has been estimated, is likely to multiply four-fold during the next ten years. How is it to be handled? The reports of two committees dealing with different aspects of the problem have been issued recently. One, the official report of the Millbourn committee appointed by the Minister of Transport and Civil Aviation in 1955, deals with the ground handling of passengers and freight and the maintenance facilities at London Airport;* the principal proposals are that the central terminal area shall be extended, by the elimination of No. 4 S.E./N.W. runway, to provide space for new passenger-handling buildings, a freight building with 300,000 sq. ft. floor area, car parks, aircraft park and additional maintenance area; and that the gate-and-pier system should be adoped to enable passengers to walk between the terminal building and the aircraft, in place of the present bus journey. (It always was rather a mystery why the bus system was ever adopted in the central area.)

The other report,† which is being circulated to all members of Parliament by the Air League of the British Empire, comprises the findings of the Air League's Air Transport Committee who were charged with the task of formulating "a comprehensive air transport policy to ensure that this country shall not only attain a share of world air traffic corresponding to its prestige and its needs as a great commercial nation, but shall also be equipped with the maximum reserves of air transport which can be available in case of war or similar emergency."

To cope with the increasing flow of traffic, the two national corporations, B.O.A.C. and B.E.A., would need to become so large that they might become less efficient. The Air League recommend, therefore, that selected independent operators should be allocated a proportion of the expected increase, and that some of the big shipping companies should be associated with the project. They recommend that there should be a closer integration of schedules, traffic and booking facilities between all such operators of scheduled services "so as to present a united British front against international competition." The proposal to give more scope to the independents would allow them to build up their fleets with more modern equipment, thus increasing their competitive value in the charter field also.

An interesting proposal for the short-term betterment of the independents' financial position is their use for "fetching and carrying" stores and equipment for the armed Services overseas. The present Service policy is to provide extensive storage space at all overseas bases for all their spares; the Air League are proposing that, by using a central store in conjunction with air transport, great economies could be effected particularly as many items of equipment do not thrive in store in tropical climates, for instance. In conditions of peace, doubtless well-worthwhile savings could be achieved by such a rationalised system; but under war conditions it seems rather doubtful whether the overseas bases would feel very happy with such an arrangement.

Besides operational considerations the Air League have also been considering the part the British aircraft industry is to play in the coming expansion. They believe that "this country ought to make an effort on a national scale" to "exploit to the full the genius and originality of British engineers and designers"; and they have suggested two projects with this in view: a "super-cargo" aircraft operating at economical speeds of the order of 500 m.p.h. and at altitudes of not less than 25,000 ft. and over ranges of the order of 2,000 to 4,000 miles. Such an aircraft is well within present engineering capacity, and, it is said, would be able to operate at 50 to 60 per cent. of current cargo rates. Looking further into the future, they speculate on the possibilities of a nuclear-powered cargo carrier.

Their second proposition appears to be more influenced by pre-occupation with "prestige" than by commercial considerations. They "feel most strongly that this country must be imaginative and reach out into the future by proceeding to develop a supersonic airliner capable of vertical take-off and landing and of crossing the Atlantic in between two and three hours," and "are satified from expert evidence . . . that this is a practical proposition within the next twelve years; and it is for us an economic necessity as well as a matter of prestige. With such an aircraft, we should regain the blue riband of the Atlantic, increase enormously our aircraft export market and under the new Defence Policy be in a position to marshal our military forces anywhere."

They cite as a possibility, among many others they have examined, an aircraft of the type that has been the subject of studies by Rolls-Royce Limited. This aircraft would employ a multiple installation of small power plants for lift and another installation of more powerful engines for forward flight. The weight penalty of the lift engine installation would, it is claimed, more than be offset by the absence of heavy undercarriage and of airframe structure weight necessitated by wing lift.

Such an aircraft, they contend, could be built within the next twelve years to operate at 1,500 knots at about 60,000 ft. at an all-up weight of around 200,000 lb. with a payload and fuel capacity of half that weight, and carrying about 135 passengers in the tourist configuration. It could fly from London to New York in about 2½ hours. Such an aircraft would enable the whole of this country's inter-continental air traffic to be handled in a field the size of Hyde Park (but it would be a rather noisy field and hardly suitable for city-centre operation).

The realisation of this dream within 12 years, even with all the national aircraft industrial resources backed by Government and City support, seems optimistic; it is an entirely new conception involving vast technical problems on many fronts. It is, moreover, by no means certain that, in the present state of knowledge, the supersonic airliner can be made an attractive commercial proposition; what is fairly certain is that, if it should prove feasible, there will have to be some very drastic thinking on air-traffic control throughout the world before any commercial operator would dare to use such an aircraft in passenger service. This third aspect of the expected air traffic expansion—with which neither of the two committees mentioned have been concerned—is possibly the most important consideration of all. Already the existing air-traffic control system is approaching saturation, and it is evident that much more of the taxpayers' money will have to be devoted to solving this problem if there is not to be chaos in the air in the quite-near future.

* Report of the London Airport Development Committee to the Minister of Transport and Civil Aviation. H.M.S.O. 2*s*.

† The Future of British Air Transport. Air League of the British Empire.

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NAPIER OFFSHOOT IN U.S.A.

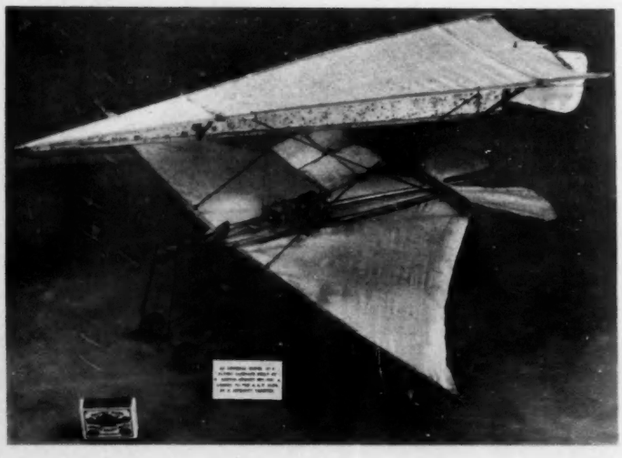
In order to provide adequately for the handling of its growing business interests in the United States of America, D. Napier and Son, Limited, Acton, London, W.3, have formed a new company, Napier Engines Incorporated, with headquarters in Washington, D.C. Napier's interests in the United States have hitherto been in the hands of technical representatives.

The president of the new company is Mr. H. Sammons, C.B.E., M.I.Mech.E., F.R.Ae.S., managing director of D. Napier and Son. The executive vice-president is Mr. J. C. K. Shipp, who has long been resident in the United States representing the aviation interests of the English Electric Group, of which Napier is a member. Mr. L. O. Brooks and Mr. A. Gualtieri, formerly Napier's representatives in the United States, are executives of the new company, the former to look after matters relating to the Napier Deltic Diesel engine and Napier turbo-blowers, and the latter those relating to Napier's aviation interests.

The principal objects of the company are to sell Napier's products; to make contracts with customers for the overhaul of Napier engines; to sub-contract the overhaul and servicing of Napier engines, and to provide and distribute spare parts.

SANTOS-DUMONT MODEL PRESENTED TO BRAZIL

A model aeroplane constructed by the Brazilian-born aviation pioneer, Alberto Santos-Dumont, has been presented to the Brazilian Government by Vickers-Armstrongs (Aircraft) Limited, who purchased it from Mr. H. Jephcott-Tanburn, O.B.E., to whom it was given by Santos-Dumont himself in 1922. It is not known if the model was ever successfully flown, but it was almost certainly one of a series of design studies which led eventually to the construction of the "14-bis" in 1906—a tail-first biplane in which Santos-Dumont achieved the distinction of becoming the first man in Europe to fly a powered aeroplane; on November 12, 1906, he flew for 220 metres before official witnesses of the Aero Club de France. The aeroplane was fitted with octagonal ailerons—the first application of ailerons to a powered aircraft.



The model, which can be seen in the accompanying illustration, is a clockwork-operated tractor semi-biplane, with tail and amidships elevators and a rear rudder; it was at first thought to date from about 1899, but the aviation historian, Mr. C. H. Gibbs-Smith, believes that it is more likely to have been built around 1906 when Santos-Dumont turned his ideas from lighter-than-air to heavier-than-air machines. He had previously experimented with power-driven balloons.

ENGINEERING FIRMS IN THE FREE TRADE AREA

7—VITTORIO NECCHI S.p.A., PAVIA, ITALY

The rapid expansion in the output of sewing machines by Vittorio Necchi S.p.A. since its foundation in 1947 is a further example of the competitive strength of Italian manufacturers in certain branches of the engineering industry. By 1956 the company's labour force had grown to 5,000, the factory covered an area of 20 acres and output had reached about 1,000 sewing machines per day, of which only 40 per cent. could be absorbed by the Italian home market and the balance was exported to 104 countries. The basis of this rapid expansion was a successful sales campaign in the United States, the original home of the sewing machine, which now takes about 40 per cent. of the Italian company's output.

It has been estimated that the world production of sewing machines in 1955 was 6·6 million units. The United States is by far the largest individual market and has hitherto been the leading producer, but in recent years American manufacturers have been experiencing difficulty in meeting the competition of imports, particularly from Italy, West Germany and Japan. In 1955, Japanese production totalled 1·8 million units or 27 per cent. of the estimated world output. In this country sewing-machine manufacturers have hitherto been protected by an import duty of 15 per cent. and have not felt the full force of foreign competition but, if the United Kingdom joins the Free Trade Area, British manufacturers will have to meet competition on equal terms from Germany, Italy and Spain, though they may well expect a continuation of the present total prohibition of imports from Japan.

GROWTH OF SALES

The early history of the sewing machine is largely synonymous with the growth of the Singer organisation in the United States and the United Kingdom. It has been estimated that since the establishment of the American company in 1851 more than 100 million Singer machines have been sold. As early as 1856 this company introduced instalment selling, and the scheme became the prototype for hire-purchase business. In this country the Singer Manufacturing Company started production in 1867 at Glasgow and moved to the present site at Kilbowie, Clydebank, in 1882. Initially, component parts were manufactured in the United States and assembled in this country but, since even in the early years the two factories were supplying a world market, a certain amount of specialisation took place, the United States company tending to concentrate, though by no means exclusively, on industrial machines and the British on domestic.

The growth in output of sewing machines in both the United States and the United Kingdom owed a great deal to the selling methods adopted by the Singer organisation. The Singer Sewing Machine Company, Limited, responsible for sales in the United Kingdom, grew from a single shop in Glasgow in 1856 to 500 shops with 5,000 salesmen canvassers by the end of the century. In 1903 the organisation was divided into two major departments, one concerned with retail sales of domestic sewing machines and the other with industrial machines. By the outbreak of war in 1914 three new schemes had been introduced to encourage the sale of domestic machines, the establishment of the educational and the embroidery departments and the issuing of a house magazine, *The Red S Review*. The educational department aimed at introducing Singer machines into schools throughout the country and classes were formed for the instruction of teachers in order to assist students taking courses in domestic science.

Mention has already been made of the early introduction of credit sales, and hire purchase has continued to be important in developing the home market. In 1955 it was stated that 60 per cent. of retail sales in the British market were on hire purchase. After the last war the company introduced a new method of collecting the instalments, which are now posted monthly to a central office covering the whole country instead of being collected weekly. It has been stated that the number of arrears accumulating is small compared with that under the old system, but this may, of course, be due mainly to the higher level of prosperity and lower incidence of unemployment compared with the pre-war years. On the industrial side the company started a service in 1905 to assist customers to design and lay out new factories.

UNITED KINGDOM OUTPUT

The company's Clydebank factory covers 150 acres and the number of employees is about 14,000. The second largest producer of sewing machines is the Jones Sewing Machine Company, which is a subsidiary of the Imperial Continental Gas Company, and with its associated company, British Sewing Machines Limited, is estimated to account for about 10 per cent. of the United Kingdom output, compared with 80 per cent. in the case of Singers. Early this year Singer and Jones, together with Adamson and Company (Machines), Limited, Bellow Machine Company, Limited, and Wilcox and Gibbs Sewing Machine Company, formed the British Association of Sewing Machine Manufacturers. In 1956 the production of sewing machines for the home market totalled 114,000 compared with 127,000 in the previous year. Exports of complete sewing machines in 1955 totalled 420,000, valued at £5·7 million, and of sewing machine heads 252,759, valued at £2·3 million. Imports of complete sewing machines totalled only 12,482, valued at £685,332, in 1955. Total British production of sewing machines in 1955 was therefore about 547,000 and total sales on the home market 139,000. Imports and exports are not available by number for 1956, but there was little change in the weight or value of imports compared with 1955. Nearly half the imports by weight and 70 per cent. by value consist of industrial machines. So far as domestic machines are concerned therefore, it is clear that, at any rate up to the end of 1956, British manufacturers were not suffering seriously from foreign competition.

AMERICAN MARKETS

The position is very different in the United States, where imports have accounted for nearly half the total sales in recent years. In June, 1957, the second largest United States manufacturer, the White Sewing Machine Corporation, announced that it would increase imports of low-priced machines in an attempt to retain its position in the market. These imported machines will be built to specifications laid down by the American company. Before the war, United States imports were valued at an average of 165,000 dols. over the three years 1937 to 1939, of which half were obtained from the United Kingdom and 40 per cent. from Germany. By 1951 the value of imports had risen to 13·2 million dols., and by 1956 to 25·6 million dols. The number of machines imported in 1956 was 1·4 million. Imports from the United Kingdom and Germany have both increased substantially compared with the pre-war average, but two new suppliers have entered the field, namely Italy and Japan. In 1946 Japan supplied 50·2 per cent. by value of all imports, Italy 16·4 per cent., Germany 14·9 per cent. (there appears to have been a sharp fall in value per unit of German machines imported into the United States compared with the pre-war years), and the United Kingdom 12·5 per cent.

The foreign invasion of the United States market followed two distinct patterns; the Italian and German manufacturers concentrated on relatively high-priced quality machines, while the Japanese concentrated on the low-priced market. Vittorio Necchi S.p.a. began to sell in the United States market in 1947, but their sales campaign was not fully developed until 1949. By 1954 the Necchi Sewing Machine Sales Corporation claimed to be supplying 5 per cent. of the total United States market or about 10 per cent. of the market for quality machines. This success was based initially on the Necchi zig-zag machine, which was the first medium-price machine capable of performing intricate operations such as making button holes, sewing on buttons and blindstitching to fancy embroidery. Such work was possible previously only with industrial sewing machines or by means of complicated appliances. The full Necchi range as introduced in the United States in 1949 comprised eight straight-sewing units priced at 142 dols. to 235 dols., and eight machines for fancy sewing priced at 205 dols. to 318 dols. Prices of American Singer machines at that time ranged from 89·50 dols. for a portable machine to 321 dols. for a console unit.

The leading American manufacturers appear to have been surprised at the success of the Necchi zig-zag machine, and both Singer and White introduced zig-zag machines for sale to the housewife in 1952 (they had already been selling similar machines to dressmakers and professionals). Meanwhile the principal European manufacturers, and specifically the Necchi Sewing Machine Sales Corporation, had transferred their main sales effort to a medium-priced general-purpose machine. To further their sales campaign Necchi adopted a number of the methods developed by Singer and instituted an extensive home-sewing education programme.

A number of factors facilitated the expansion of sales of foreign machines in the United States market in the immediate post-war years. There was a considerable back-log of demand resulting from a cut in production during the war; import duties were reduced in 1948; and there was a prolonged strike at the Singer factory which suspended production for several months. In addition, the leading department stores and mail order houses were anxious to be in a position to offer sewing machines under their own name, and since the leading American manufacturers already had their own retail outlets, they tended to turn to foreign producers. This last factor influenced particularly the sales of Japanese machines, and by June, 1957, Sears Roebuck were offering in their catalogue four Japanese machines and one American. They were also selling a relatively high-priced West German machine though this was not included in the catalogue. In order to prevent foreign manufacturers exploiting a similar situation in the United Kingdom, the Singer Sewing Machine Company, Limited, have started marketing through a selected number of department stores in addition to their own retail outlets.

GERMANY AND JAPAN

The principal German manufacturers of sewing machines are G. M. Pfaff, A.G., Kaiserslautern, and Singer Nahmaschinen A.G., Frankfurt. The former company sells domestic machines in the United States through A. C. Weber and Company, Incorporated, Chicago, and industrial machines through Willcox and Gibbs. The total German production of domestic sewing machines fell from 605,000 in 1951 to 475,000 in 1953, recovered to 608,000 in 1955 but fell back again to 581,000 in 1956. Before the war the industry was predominantly an export one and about 70 per cent. of total output went out of Germany. Though the published production and export figures since the war are not strictly comparable, exports are said to have accounted for about 50 per cent. of production in 1954 and 1955. A large part of the exports in recent years appears to have

consisted of sewing-machine heads and other parts for assembly abroad. Thus, according to the German trade returns, exports of complete domestic machines in 1956 amounted to 108,000 valued at £2·8 million. Exports of other (mainly industrial) machines and parts, however, were valued at £9·6 million. United States imports of domestic sewing machines from West Germany in 1954, however, comprised 288,000 machines valued at £1·3 million and in 1956 the value had risen to £1·5 million, though the number is not recorded.

JAPANESE EFFORTS

The growth of the Japanese sewing-machine industry since the war has been very rapid. In 1947 output of domestic and industrial machines comprised 150,000 units of which 10,000 were exported: in 1955 production totalled 1,803,000 of which 1,700,000 were exported. Initially the quality of the Japanese machines was poor but in recent years it has been comparable with that of European products. United States dealers are, in fact, reported to have sold several thousand Japanese machines in the American market at the price of American machines: in one instance a machine imported at 39 dols. is reported to have been sold at 200 dols.

The low export prices of Japanese machines are said to be due to the fact that Japanese wage rates are only about half those in Western European countries and also to the indirect export assistance received by Japanese manufacturers. Although there are no direct export subsidies, the Japanese producers are entitled to sell the dollars resulting from export sales at a relatively high rate of exchange in order to bridge the gap between the export and home market prices. In practice, however, this assistance does not appear to be very large, since in 1954 the Juki Industrial Company, Limited, is reported to have been producing a treadle model which sold on the home market at a wholesale price of £17 and a retail price of £23 10*s*.; the export price f.o.b. was £15. In Canada, West Africa and Australia, however, Japanese manufacturers were, in 1956, offering machines at prices 40 to 60 per cent. below those of comparable British models.

The United States market accounts for over 40 per cent. of total Japanese exports of sewing machines. The balance is spread over a large number of countries of which the most important are Hong Kong (90,000 in 1956), Indonesia (83,000), Chile (55,000), Peru (47,000) and Canada (42,000). As stated above imports of Japanese sewing machines into the United Kingdom are prohibited and this appears to be true also of the principal European markets. In June, 1957, it was reported that two Japanese manufacturers, Toyo Menka Kaisha and Nishizawa Sewing Machine Industrial Company, were planning to establish production of sewing machines and parts as from September, 1957, in Sao Paulo, Brazil.

FUTURE DEPENDS ON POLICY

The past year has provided some evidence that, apart from the United States market, the rapid expansion in Japanese sewing machine exports has reached a peak. Total exports of domestic machines at 1·4 million showed a slight decline of 4 per cent. compared with the previous year. Exports to the United States rose from 566,000 to 630,000; hence exports to other countries fell by about 13 per cent. United Kingdom exports on the other hand rose from £8 million in 1955 to £8·7 million in 1956, and German exports (including industrial machines and parts) from £12·1 million to £12·4 million. Even in the United States market United Kingdom and West German manufacturers slightly improved their position in 1956 *vis-à-vis* Japanese and Italian producers. The last two years have therefore seen a general stabilisation of the position after the rapid development first of Italian and then of Japanese production.

So far as the European Common Market and Free Trade Area is concerned, the future must depend very largely on the policy adopted towards Japanese products. If these were to be freely admitted into European countries and the United Kingdom, they would probably, by analogy with the position in the United States, secure a substantial part of the European domestic market. It seems more probable, however, that either Japanese machines will continue to be excluded or that a high import duty will be imposed. If this is the case the formation of a Free Trade Area might result in very little change in the overall position so far as Europe is concerned. In general most of the principal European producers already supply the bulk of their own home market and intra-European trade is largely confined to exports from the United Kingdom, West Germany, Italy and Switzerland to those countries such as Belgium, Holland and, to a lesser extent, France, which are not important producers. There is also a small intra-European trade in specialised types of machine. Import duties at present range from 6 per cent. in the case of Belgium and Holland to 10 per cent. in Western Germany, 15 per cent. in the United Kingdom and 20 per cent. in France. Removal of these duties would probably not be sufficient to cause a marked change in the pattern of trade, though obviously producers in the United Kingdom and France would have to meet intensified competition from West Germany and Italy.

SPANISH INTERVENTION

The position of Spain in relation to the Free Trade Area may prove to be of some importance. Vittorio Necchi have established a subsidiary there and total Spanish production amounts to about 200,000 machines per annum of which about 30 per cent. are exported. This is not an appreciable quantity in relation to European consumption but, in view of the low wage rates in Spain, production and exports might expand rapidly. Even with the present 15 per cent. import duty it is thought that Spanish sewing machines may secure a foothold in the United Kingdom market. France already imports some sewing machines from Spain but the total value of such imports in 1955 was only £36,000. It is generally considered that Spain is unlikely to become a member of the Free Trade Area, at any rate in the initial stages.

The principal threat to European and British manufacturers may well be an intensified Japanese competition in non-European markets. The principal British, German and Italian manufacturers all rely heavily on exports to keep their productive capacity fully occupied. If a marked reduction in exports occurs it can only result in intensified competition within the Free Trade Area. Hitherto European sewing-machine manufacturers have enjoyed some protection by the elaborate distribution and educational organisations which they have built up, and it is significant that Necchi announced some years ago that, having established themselves in the United States market, they proposed to do the same in this country. Nevertheless the threatened invasion has not occurred, probably because the United States is the only market of which, say, a 10 per cent. share would justify the heavy development expenditure necessary to obtain a foothold. Although sales of Necchi machines in the United States were started by a Polish refugee with virtually no capital behind him, it was not long before the Necchi Sewing Machine Corporation was budgeting to spend 100,000 dols. in six months to increase home-sewing.

The Free Trade Area as a whole will provide a market comparable in size to the United States, and this will justify more intensive sales effort than would be warranted in a single European country. Moreover, judging from United States' experience, there is scope for a very considerable increase in total sales of sewing machines in European countries. In 1954, for example, sales of sewing machines in the United States amounted to 12 per 1,000 of population against 10 per 1,000 in Switzerland, 5 per 1,000 in West Germany and only a little over 2 per 1,000 in the United Kingdom and Italy.

VELINDRE CONTINUOUS STRIP ANNEALING PLANT

What is stated to be the first continuous cleaning and anne ling plant for steel strip to be installed in Europe, has recently been started up at the Velindre Works of the Steel Company of Wales Limited. The Velindre Works are five miles north of Swansea. As already stated in our columns, on page 45 of our issue of July 13, 1956, the plant is capable of handling, at 600 ft. a minute, steel strip of the width required for tin-plate production, which strip, hitherto, has been annealed in batch-type furnaces, the process taking approximately 84 hours.

The new continuous annealing plant, a general view of which is shown below, has a length of 210 ft. and a height of 53 ft., and the total length of steel strip passing through the furnace and cooling zones at any one time is about half a mile. The plant can deal with a 30,000 lb. coil of strip, 38 in. wide and of normal tin-plate gauges, approximately every hour.

Coils, after finish rolling in the cold-reduction rolling mill, are loaded by a crane or tractor on to entry jacks from which they are pushed on to one of two mandrel-type paying-off reels. From these reels the strip is unwound and, as the operation is continuous, the leading end of each coil is sheared and welded to the trailing end of the preceding coil.

The strip is then passed through a vertical alkaline cleaning unit which removes all trace of rolling oil and dries the strip before it passes through the looping tower prior to entering the furnace. The looping towers at the entry and exit ends of the plant serve as a reserve of

The continuous annealing plant at the Velindre Works, near Swansea, of the Steel Company of Wales, Limited. The plant has a height of 53 ft., and a length of 210 ft. It can deal with strip 38 in. wide and of normal tin-plate gauges, at approximately 600 ft. per minute, or a coil of 30,000 lb. approximately every hour.

material in order that the strip does not have to be stopped in the furnace while the coils are being welded at the entry end or taken off at the delivery end.

From the looping tower the strip enters the heating section of the furnace which contains five heating passes. In this section the strip is heated by means of town gas to the annealing temperature of 1,350 deg. F., in 17·4 seconds. After reaching this temperature, the strip passes into an electrically heated two-strand soaking section and remains there for a sufficient time for the full metallurgical effect to take place.

Following the soaking section there are three main cooling stages. In the first cooling stage there are three passes for slow air cooling, designed to reduce the temperature to about 800 deg. C. In the second stage there are 16 rapid-cooling passes in which water-jacket cooling further reduces the temperature to about 250 deg. F. In the final cooling stage, two forced-air cooling passes are included to bring down the temperature of the strip to approximately 150 deg. F.

During the heating, soaking, and cooling cycle a neutral gas mixture is circulated inside the plant to prevent the oxidation of the strip. The three units which generate this gas (termed "DX") at a rate of 6,000 cub. ft. per hour are installed in the same building that houses the generators for the similar "H.N.X." gas used in the batch-annealing furnaces.

The continuous annealing plant has been manufactured and installed by the Incandescent Heat Company, Limited, Cornwall-road, Smethwick, Birmingham, 40, as main contractors; it was designed in collaboration with the Incandescent Company's associates, the Drever Company, of Pennsylvania, U.S.A. The strip handling equipment has been supplied by Davy and United Engineering Company, Limited, Park Iron Works, Sheffield, 4.

TITANIUM PRODUCTION IN SHEFFIELD

Although first isolated as an element as long ago as 1791, titanium has become available as a commercial material only during the last decade but, as our columns have borne witness on several occasions, the high strength-to-weight ratio of the metal, and its excellent corrosion resistance, have already found a number of applications, mainly in the aircraft industry for parts of jet engines and for air frames.

After manipulating large titanium billets imported from the United States for several years, William Jessop and Sons, Limited, Brightside Works, Sheffield, 1, who possessed considerable experience in the melting and forging of complex high-grade alloys for the production of gas-turbine discs and similar objects, decided to install a titanium-melting plant. This plant, built entirely as a private venture at a cost of £300,000, came into production early in 1956; it embodies melting furnaces constantly producing titanium ingots of up to 20 in. in diameter and up to 1 ton in weight. Such ingots, we are informed, are larger than any produced in Europe. The consumable-electrode double-melting process is that employed. The raw material is in spongy finely-divided form, termed titanium granules, purchased mainly from Imperial Chemical Industries Limited, and in the production of titanium alloys this is mixed with appropriate quantities of manganese, aluminium and tin, also in granulated form, and consolidated into compacts under a 2,000-ton press. The pressed compacts are then introduced into a vertical chamber which is evacuated and the compacts are joined together by welding to form a cylindrical electrode. This is fed down into a water-cooled evacuated copper crucible, an arc is struck and melting begins. The molten metal solidifies rapidly on coming in contact with the water-cooled copper mould walls and an ingot is built up. In order to improve the homogeneity of the metal the ingot is remelted *in vacuo*, again in a water-cooled copper crucible, and the final ingot is taken to a lathe where its somewhat rough exterior skin is machined off.

Before the production plant came into operation, laboratory furnaces and later a research pilot plant had been engaged on investigations into existing titanium alloys and on the development of new alloys. This work has resulted in the production of five alloys given the brand name Hylite. The first, Hylite 10, consists of commercially-pure titanium having a maximum hardness of 150 Brinell numbers and an ultimate tensile strength of 30 tons per sq. in. The second material, Hylite 20, is an alloy containing 5 per cent. of aluminium and 2½ per cent. of tin. This alloy has an ultimate tensile strength of 60 tons per sq. in. and a 0·2 per cent. proof stress of 52 tons per sq. in. It is stable and readily weldable and does not become brittle under service conditions. Hylite 30, a 2 per cent. manganese, 2 per cent. aluminium alloy, is intended to be the "mild steel" of titanium metallurgy. It has an ultimate tensile strength of 44 tons and a 0·2 per cent. proof stress of 36 tons per sq. in. Hylite 40, containing 4 per cent. of manganese and 4 per cent. of aluminium, is recommended for such applications as air-compressor discs or as blade material. It has an ultimate tensile strength of 68 tons and a 0·2 per cent. proof stress of 60 tons per sq. in. Hylite 50, a complex aluminium alloy, has been developed as an air compressor disc or blade material and would be recommended for service where Hylite 40 has inadequate strength. The 50 alloy has an ultimate tensile strength of 70 tons and a 0·2 per cent. proof stress of 62 tons per sq. in. Its hardness is 360 Brinell numbers. The Hylite series of alloys, we understand, are available in the form of hand forgings, drop stampings, rolled or hammered bar, ingots or billets, and also as sheet, strip, wire and tubes.

WELDS IN EXTRA THICK PLATE

The welding of large vessels having walls of very thick steel plate for nuclear-energy applications and other large industrial fabrications presents a number of problems. Steel-plate up to 1½ in. in thickness can be successfully welded by using normal low-hydrogen electrodes and satisfactory tensile, elongation and impact properties can be obtained throughout the full thickness of the weld. Standard electrodes, however, have not been found entirely satisfactory for the welding of vessels having walls from 3 to 4 in. thick and, in particular, Charpy impact results at sub-zero temperatures have shown a very wide scatter range and have not always been up to the required standard throughout the full thickness of the weld.

This fact has led to the development of a new electrode, "Fortrex 35A," in the research laboratories of Murex Welding Processes, Limited, Waltham Cross, Hertfordshire. The work has involved the testing of a large number of 3 to 4 in. thick plates over a period of many months and about 1,000 Charpy V-notch test-pieces have been machined from the welds made in these thick plates in all the positions encountered in the welding of large spherical or cylindrical vessels.

The new electrode, it is claimed, gives all the required properties in the welded joint in extra thick plates and the weld metal has particularly good impact properties at sub-zero temperatures. It is further stated that the new electrode has all the advantages of the firm's standard "Fortrex 35" type; it is an all-position electrode; it is simple to use, slag removal is easy, and the radiographic quality of the weld metal is sound.

SCHOOL OF WELDING TECHNOLOGY

The rapid development of welding has brought an equally rapid accumulation of new technical knowledge and, in consequence, a growing demand for the dissemination of that knowledge is making itself felt. In this country, under Government leadership, very great efforts are being made to meet the demands of industry for qualified welding technologists. Between 1948 and 1957, the Summer School of Welding, organised by the British Welding Research Association, at Ashorne Hill, near Leamington Spa, has provided each year a week's course of study under the guidance of specialists, and each year the demand has greatly outrun the accommodation. Moreover, the overwhelming response to the Institute of Welding's course of evening lectures on the detail design of welded structural steelwork is further evidence of the needs of industry.

As the outcome of discussions with the British Welding Research Association, in which it has been decided to discontinue the Summer School, the Council of the Institute of Welding have undertaken to continue the educational work of the Association in the form of a School of Welding Technology. The new School will be active throughout the year and will provide short intensive courses, each dealing with a selected aspect of welding or the application of welding in a single section of engineering production.

The courses are intended for technologists having industrial experience and responsibility. Students will be assumed to possess the education of an engineer and at least a basic knowledge of the various welding processes and their use in industry. Courses will be held at the Institute's headquarters, at 54 Princes-gate, South Kensington, London, S.W.7, and students will be accommodated at the Norfolk Hotel, near South Kensington Station. So far, six courses, each comprising 10 or 11 lectures and two visits, have been organised. They will run from October 7 to 11, November 4 to 8, December 2 to 6, January 6 to 10, 1958, February 3 to 7, 1958, and March 3 to 7, 1958. The courses will deal with such subjects as the welded design and construction of pressure vessels and pipework; in general and mechanical engineering; welding in light alloys; in corrosion and heat-resisting materials; resistance welding; and the inspection and testing of welded work.

The fees for members of the Institute and employees of industrial corporate members are 12 guineas for each course, and for other persons 16 guineas. A prospectus giving further particulars of the courses, charges for accommodation and other information is available from the Secretary of the Institute of Welding, 54 Princes-gate, London, S.W.7.

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FERRO-ELECTRIC

The discovery of a new ferro-electric material, known chemically as triglycine sulphate, has been announced. The material, produced in the Bell Telephone Laboratories, New York, has a rectangular voltage hysteresis loop, and is likely to find application in switching circuits and memory devices.

Triglycine sulphate has a coercive field of 220 volts per cm. It is stable chemically and unaffected by moisture. Adequate mechanical strength permits it to be handled in thin sheets. Large single crystals can be grown quite easily, and a number of large-area slices can be cut from each crystal. Although heating beyond the Curie point (47 deg. C.) causes the material to lose its ferro-electric properties, these are regained on cooling. By replacing some of the hydrogen atoms with deuterium, accomplished when the crystal is grown, the Curie point can be raised to 60 deg. C. It appears that switching times of the order of one or two microseconds can be attained.

LIMITED LIFE DESIGN: A SURVEY OF THE PROBLEM*

By J. A. Pope, D.SC., WH.SCH., M.I.MECH.E., *B. K. Foster*, B.SC., D.I.C., *and N. T. Bloomer*, PH.D.†

Until recent years the principal basis of that part of engineering design which is conventionally called strength of materials has been freedom from deformation under the single application of a load. Neglecting cases of elastic instability this, in turn, has been based on the elastic limit or the ultimate strength of the material as measured by a static test. To arrive at a working stress the designer has used, in addition, a " factor of safety " the value of which depended upon the type of component, its condition of loading and which strength was used as a basis (i.e., a larger factor of safety was obviously needed if the ultimate strength rather than the elastic limit were used). The factor of safety is not a factor of ignorance but really a factor of tradition and experience, and as such has formed a very sound basis for design when the limit is set by the static strength of the component. In static design the points to be taken into account are: (1) the maximum load which the component will have to withstand during its life and the resulting maximum stress which might occur in any part of the component; (2) the representative static strength of the material; and (3) a suitable factor of safety which makes allowance for such considerations as variation in quality of material, unknown manufacturing and assembly stresses and variations from the theoretical conditions of stressing on which the estimate in (1) was based.

Consider now a component which, during normal use is subjected to varying loads and suppose the sequence of loading is as shown in Fig. 1 (this load sequence was obtained by Muller-Stock[1]). Obviously, the maximum load is at P. The designer, when designing on the principles of static design quoted above, is interested only in the single value of the load at P. If the component is made to withstand a load greater than P then there seems to be no reason for predicting impending failure and the component might be expected to last for ever. If an error is made in the design or if the component has to withstand an unexpectedly large load at P, failure will occur. Such a failure may result in a breakdown of the whole machine of which the component forms a part, but often, if the material is at all ductile the failure will be by plastic distortion rather than rupture, and a portion of the load will be taken by neighbouring parts thus avoiding catastrophic failure. If this were the case the distortion of the component would be a warning of serious conditions and remedial action could be taken. In this latter eventuality the component will have " failed safe "—an expression to be defined later. Thus it is seen that in static design the successful design is automatically one where the life of a component (neglecting corrosion, wear and other factors outside the realm of strength of materials) is infinite. This is the classical method of design which itself has many difficulties, but recently it has proved to be an inadequate means of assessing the strength of many engineering components.

CONDITIONS FOR DYNAMIC DESIGN

The question now is what has necessitated a departure from the relatively simple principles of static design? The short answer is that in many branches of engineering the fatigue strength of the material has become the limiting factor; the component which had to withstand the load sequence shown in Fig. 1 might fail by fatigue even though the load P never exceeded the static strength of the material. When fatigue failure is possible, dynamic instead of static design methods must be used. Metal fatigue is becoming increasingly important, and since in fatigue even ductile materials fail in a quasi-brittle manner there can be no hope of load shedding as previously discussed and catastrophic failure is very likely to occur.

Some of the reasons for the increasing prevalence of fatigue failure will now be considered. For simplicity, assume that a material is subjected to an alternating stress of constant amplitude, as shown in Fig. 2. Then whether the design is static or dynamic, S will be the stress on which the calculations will be based. Suppose the elastic limit S_y is m times the fatigue strength S_f and that for static design the factor of safety to be adopted is k (based on S_y). Then $S_y = m\,S_f$, $S\,k = S_y$ and hence $\frac{k}{m} = \frac{S_f}{S}$. If then failure is to be prevented S must never exceed S_f, ($S_f > S$) and consequently k must always be greater than or equal to m, ($k > m$). Therefore, provided $k > m$ the fatigue limit will not be exceeded and static design principles can be used.

TABLE I.—*Direct Stress Fatigue Tests on Various Joints in Chromium Copper Steel, with Surfaces as Rolled. Schulz and Buchholtz, Ref.* 10)

Form of joint	Endurance limit	
	Tons per sq. in.	Per cent.
Riveted with double butt strap	9·5	100
Double-T joint	3·8	40
Double-V butt-weld	8·9	93
Single-V butt-weld	8·3	87
Single-V butt weld inclined at 45 deg. to the direction of tension	9·5	100

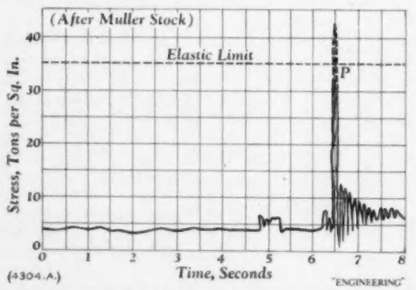

Fig. 1 A typical load sequence to which a component is liable to be subjected under normal conditions. The occasional high stress, P, could bring about failure.

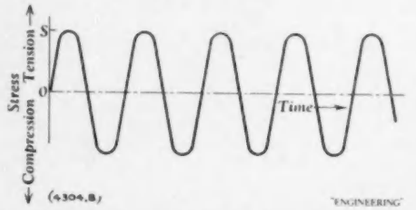

Fig. 2 Regular alternating stress sequence of constant amplitude; though not large, the stress may bring about a fatigue failure.

In recent years improved methods of stress analysis, together with tests on actual components, have allowed smaller factors of safety to be used (i.e., k has been decreased). Furthermore, advancing metallurgical knowledge has produced materials (particularly light alloys) with high static strengths but without a corresponding increase in fatigue strength, which implies that m has been increased (see Fig. 3, which summarises some data obtained by Templin[2]). Thus the designer may, by using his traditional values of k in connection with the static properties of the material, produce a component in which m exceeds k and fatigue failure might occur. In addition, methods of construction might also alter the value of m and Table I gives values of the fatigue strengths of riveted and welded joints. It will be seen that in certain cases, the fatigue strength of the welded joints is some 60 per cent. smaller than that for the equivalent riveted joints. A great deal of care must be taken when changing from riveted to welded construction since it is quite possible in so doing to change from the condition $k > m$ to $k < m$ and the fatigue strength becomes the limiting factor of design.

These considerations do not explain why the values of k should not be increased to allow for the new conditions, but an examination of the fatigue (or S-N) curves for some typical alloys will clarify this point.

Fig. 4 shows the fatigue curve for mild steel and the horizontal portion BC implies that the metal has a definite fatigue limit: i.e. if the amplitude of the oscillating stress is less than 18 tons per sq. in., the specimen will have an infinite life. In this case the designer can, and often does, use an increased factor of safety to allow for the effect of a live load and still use static design methods. However, in Figs. 5 and 6, which are fatigue curves for an aluminium alloy and for steels at high temperatures, respectively, there are no horizontal portions and so if a component made from such a material has to withstand fluctuating loads it must be accepted that it will eventually fail by fatigue. (The data shown in Figs. 5 and 6 were obtained by Johnson and Oberg,[3] and Tapsell,[4] respectively.) In such cases of fluctuating loads the designer has no alternative but to design for a limited life, using dynamic design methods. Life may also be limited by considerations such as creep (in the case of gas-turbine blades) or explosion (guided missiles) or even by obsolescence (aircraft) and in such cases any parts which will be required to carry fluctuating loads must be analysed by dynamic design methods in order to see if they are likely to fail by fatigue within their prescribed lives or alternatively are too strong and consequently constitute an uneconomical design (this latter point is particularly important in aircraft design where weight is at a premium). The life of a component may thus be fixed by specification which, under simple conditions of loading, would fix the working stress allowed as that being read off the relevant S-N curve. For example, if an aluminium alloy is required to have a life of N_1 applications of stress then, from Fig. 5, the working stress should be S_1. If due to a design error or due to lack of accurate information the component was subsequently required to carry an oscillating stress S_2, ($S_2 > S_1$) its life would be shortened to N_2; i.e., it would only last $\frac{N_2}{N_1}$ of the specified life. Thus we see that whereas in static design the static strength is the limiting factor giving a clear-cut division between success and failure, in dynamic design, due to the interplay between stress and life, no such sharp division exists. One might be led to conclude then, that exceeding the limiting dynamic loading would lead only to a shortening of life and would not be as serious as exceeding the limiting static loading which would cause immediate failure. If there were any sign of the imminence of fatigue failure this would, perhaps, be true but there is no such sign and if a component forming a vital part of a machine or structure fails before its design life it will do so without warning

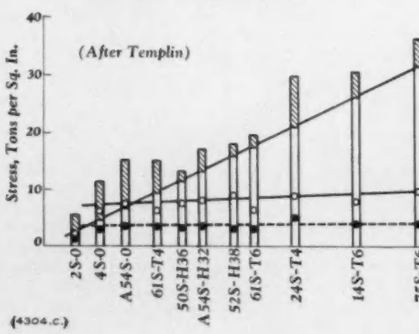

Fig. 3 Mechanical properties of light alloys; the alloys to the right are of recent production and, though they have a high U.T.S., their endurance limit is only slightly greater than the early alloys.

* Full text of an article amplifying a paper originally read before Section G of the British Association at Sheffield on September 4, 1956.

† Professor Pope is head of the department of civil and mechanical engineering, University of Nottingham. Both Mr. Foster and Dr. Bloomer were formerly of Professor Pope's department, but Mr. Foster is now at the Industrial Group Headquarters, U.K.A.E.A., Risley, nr. Warrington, Lancashire; Dr. Bloomer joins the Coventry Technical College for the new academic session.

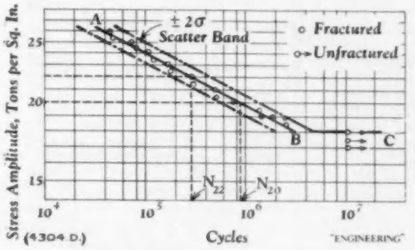

Fig. 4 Fatigue curve for mild steel.

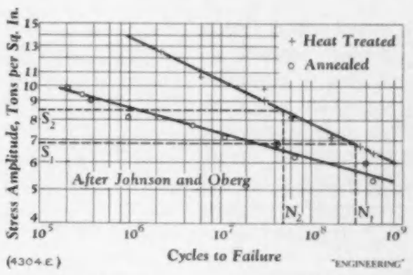

Fig. 5 Fatigue curves for aluminium alloy.

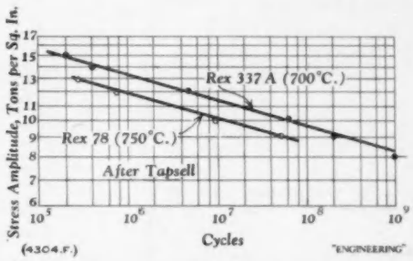

Fig. 6 Fatigue curves for high temperature steels.

and possibly with calamitous results. The problem, then, facing the designer is to ensure that, in no circumstances will failure occur at less than a specified life.

Accurate design on a life basis is difficult for a number of reasons. Three of the major ones are: (1) the scatter of fatigue test results; (2) the presence of stress raisers; and (3) the formulation of a law of cumulative damage.

SCATTER OF RESULTS

Even from laboratory fatigue tests on polished specimens the scatter in results is so great that an accurate estimation of life is very difficult if not impossible. Certainly statistical methods must be used. With completed engineering components the situation is worse. Fig. 7 shows the scatter in fatigue results, after Clayton-Cave *et al.*,[5] for polished specimens of the same steel which were subjected to the same range of stress but tested in different laboratories. The scatter at a given stress range can be illustrated by choosing two values of life which contain between them 95 per cent. of the results ($\pm 2\sigma$ using a lognormal distribution) and specifying their ratio. Thus the maximum and minimum scatters are 7 : 1 and 1·4 : 1 respectively, while for the results as a whole the scatter is 6 : 1.

Table II gives the results obtained by one of the authors from one hundred polished specimens made from the same bar and stressed in identically the same manner in similar machines. The results are arranged according to life and therefore the table gives an impression of the distribution obtained. The scatter is over 3 : 1. Reference to Fig. 4 (which was obtained from tests on the same steel) shows that this 3 : 1 scatter represents a change of only 1·1 : 1 in the change of stress but nevertheless, if life is to be used as a basis for design, the question of scatter is the first difficulty to be faced.

So far polished specimens only have been considered. When complete engineering machines or structures built up of a number of parts are examined, the scatter in each component may be considerably modified. In this kind of problem a statistical approach is essential and this aspect will be dealt with later.

STRESS RAISERS

In polished specimens there are no stress raisers such as notches, grooves, or fillets which in an engineering component are unavoidable. Stress concentration factors have only been considered important during the last 20 years which coincides with the period during which dynamic design has become increasingly essential. The reason for this is quite simple. Under static loading (and therefore with static design) stress raisers are rendered ineffectual by plastic flow of the metal at the point of high stress. Under fatigue conditions, however, since the elastic limit is never exceeded stress raisers more nearly attain their theoretical values and consequently become of prime importance. Fortunately there are plastic deformations on a microscopic scale and these permit some alleviation of the stress raiser during fatigue stressing so that the geometrical stress concentration factors for severe stress raisers are not realised. Nevertheless it may generally be said that fatigue failure takes place at stresses below the yield strength of the material and therefore the absence of general plastic flow prevents the elimination of the stress raisers. In dynamic design, then, stress raisers should be avoided or reduced to as small a value as possible.

Fig. 8, column three, this page, shows the fatigue curves (after Barson[6]) obtained for a polished and a cracked (quenching crack) specimen. With higher ranges of stress the effect of the crack on the life of the specimen is less pronounced and with a life of 10^4 cycles it has no effect whatsoever. However, since most components will require an effective life far in excess of 10^4 cycles a stress raiser must be regarded as at least partially active. Initial plastic overstrain will not reduce the range of stress at the stress raiser but will produce a localised residual stress which may have a beneficial effect if the material is sensitive to changes in mean stress. It can, therefore, be seen that since the stress raiser is so important, tests on small polished laboratory specimens are of limited value to the designer. For effective design data fatigue tests on typical components are essential.

CUMULATIVE DAMAGE

In the previous paragraphs only the effects of oscillating stresses of constant amplitude have been considered, but loads experienced in practice almost invariably produce stresses of varying amplitude and the next problem is whether the varying amplitude of the oscillating stress can be allowed for and if so on what basis can its cumulative effect be assessed from the point of view of design?

The problem is extremely complex. Fundamentally it depends on what physical changes take place in a metal during fatigue, what damaging effect these changes have and how this damage accumulates and leads to ultimate failure. Much research into this problem is still required. The only hypothesis given in this paper is one formulated by M. S. Miner[7] and assumes (*a*) that for constant amplitude stress cycles the damage done per cycle is the same throughout the life of the component, and (*b*) that the damage produced at one stress level is effective at all subsequent stress levels. The hypothesis is supported by a limited amount of experimental evidence and represents the best " tool " the designer can be given at the present time.

Miner's law of cumulative damage supposes that a piece of metal subjected to cyclical stresses has a certain " life " and that after this life has been used up it will break. With each application of load a small amount of damage is done to the material and this accumulates until the total reaches the limiting amount which represents its life. It is further supposed that for any stress amplitude the amount of damage done per cycle is the same throughout the life of the specimen. Referring to Fig. 5, if a piece of material is subjected to a number of stress reversals n_1 with an amplitude S_1 which is above the endurance limit and at which stress the expected life is N_1; then the fraction of life used up is $\frac{n_1}{N_1}$. If now the stress amplitude is raised to S_2, at which stress the life of the virgin material is N_2, and is applied for n_2 cycles then the fractional life used is $\frac{n_2}{N_2}$ and the total portion of the material's life which has been used will be $\left(\frac{n_1}{N_1}+\frac{n_2}{N_2}\right)$. When $\frac{n_1}{N_1}+\frac{n_2}{N_2}=1$ the material will fail. For any number of stress levels failure will occur when

$$\frac{n_1}{N_1}+\frac{n_2}{N_2}+\frac{n_3}{N_3}+\ldots\ldots\ldots=1, \text{ i.e., } \Sigma\frac{n}{N}=1.$$

For stresses below the endurance limit N is equal to infinity, hence $\frac{n}{N}=0$, and such stresses are assumed to have no effect.

If this law is to be applied to design then it must produce a safe estimate of fatigue life and experimental evidence regarding its veracity is important. Miner, himself, found the value of $\Sigma\frac{n}{N}$ to vary between

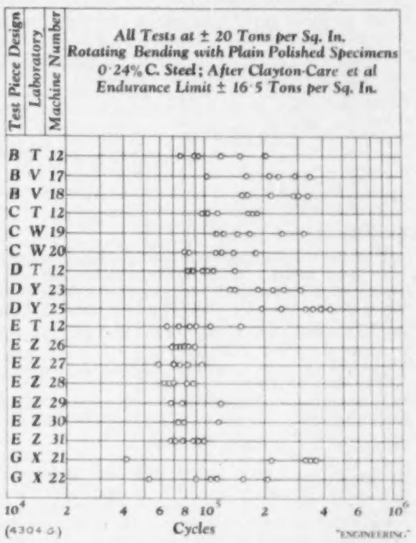

Fig. 7 Scatter of fatigue strengths as measured in the laboratory, illustrating the difficulty there is in specifying a fatigue life.

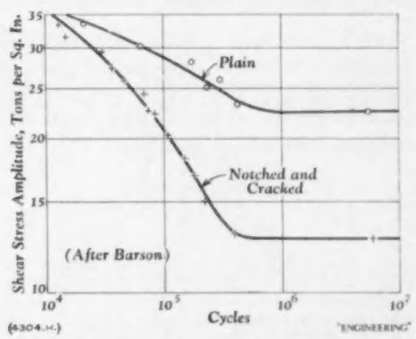

Fig. 8 Torsion fatigue tests on spring steel, showing the reduction in strength due to cracks caused when quenching.

TABLE II.—Values of N × 10^{-5} in Order of Magnitude

2·80 to 3·30	3·02 3·17 3·200	3
3·30 to 3·80	3·461 3·482 3·483 3·694 3·694 3·773 3·775	7
3·80 to 4·30	3·821 3·941 4·021 4·089 4·098 4·106 4·111 4·211 4·234 4·258 4·293	11
4·30 to 4·80	4·305 4·32 4·375 4·383 4·436 4·602 4·613 4·627 4·658 4·666 4·68 4·73 4·735 4·743 4·784 4·799	16
4·80 to 5·30	4·807 4·856 4·923 4·925 4·934 4·94 4·941 4·975 4·982 5·009 5·021 5·046 5·074 5·074 5·081 5·094 5·208 5·234 5·131 5·238 5·25	21
5·30 to 5·80	5·45 5·469 5·496 5·52 5·546 5·607 5·611 5·636 5·644 5·650 5·653 5·735 5·769	13
5·80 to 6·30	5·879 5·884 5·937 5·946 5·951, 5·967 5·981 6·054 6·122 6·13 6·134 6·218 6·284	13
6·30 to 6·80	6·302 6·314 6·346 6·389 6·474 6·732	6
6·80 to 7·30	6·995 7·293	2
7·30 to 7·80		0
7·80 to 8·30	7·812 7·886 7·964 8·245	4
8·30 to 8·80	8·346 8·41 8·768	3
8·80 to 9·30		0
9·30 to 9·80		0
9·80 to 10·30	9·945	1
	Total ...	100

All tests at ± 21 tons per sq. in. Rotating bending with plain polished specimens. 0·22 per cent. C. steel. Endurance limit ± 18 tons per sq. in.

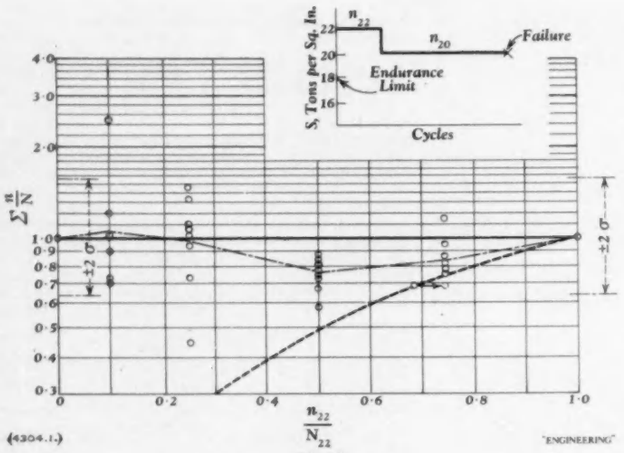

Fig. 9

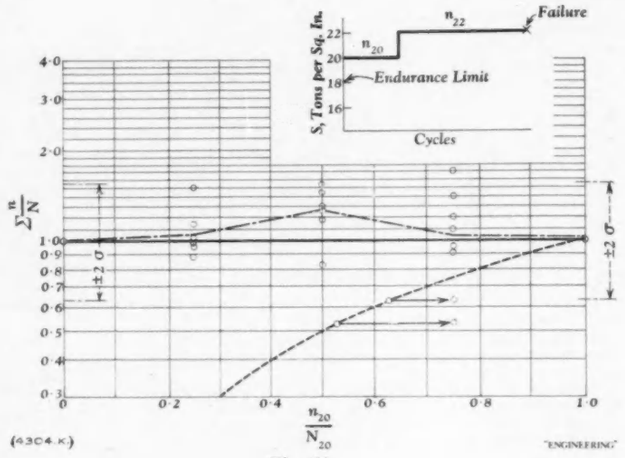

Fig. 10

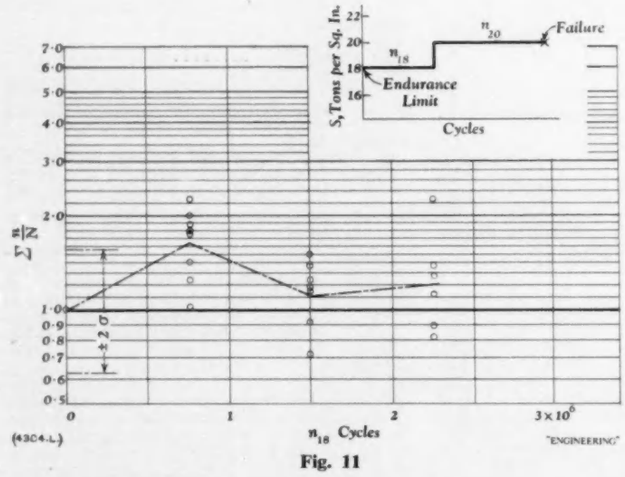

Fig. 11

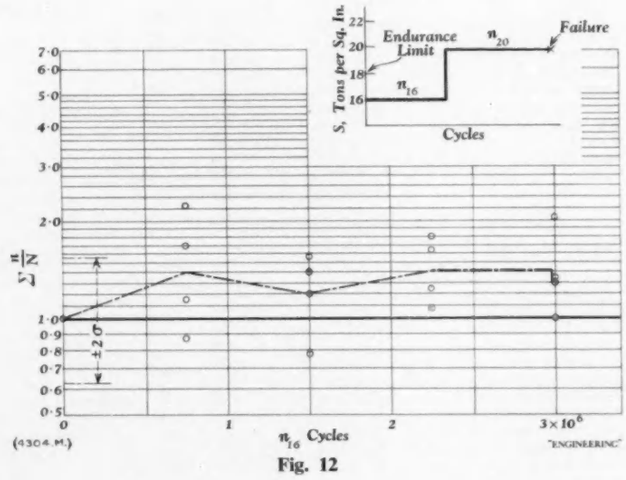

Fig. 12

1·49 and 0·61 although the average value obtained was about unity. Kibbey[8] tested specimens subjected to a sequence of ascending and descending stress amplitudes. He found that for ascending loads the mean value of $\Sigma \frac{n}{N}$ was 1·49 while for descending loads $\Sigma \frac{n}{N}$ was 0·78. It will be noted that the sequence of loading has a great effect. Miner's law does not allow for this. Marco and Starkey[8] obtained the values for $\Sigma \frac{n}{N}$ given in Table III.

Figs. 9 to 13 show results obtained from mild steel specimens at Nottingham. The symbols N_{20}, N_{22}, are as shown in Fig. 4, and the same steel was used. The sequence of loading in each case is shown in the inset in the top right hand corners where also the symbols used are defined. Particular sequences of loading have been repeated several times and the results are plotted to show the considerable scatter in the values of $\Sigma \frac{n}{N}$ obtained. The means (based on $\log \Sigma \frac{n}{N}$) are joined by straight lines. It must be remembered, however, that N, for any one stress level is not a precise measurement but has been based on the statistical mean of the results, 95 per cent. of which are contained in the $\pm 2\sigma$ scatter band. The 2σ scatter band has been shown about $\Sigma \frac{n}{N} = 1$ on the diagrams. The first two graphs substantiated the results already quoted, i.e., $\Sigma \frac{n}{N}$ is greater with ascending than with descending loads. Figs. 11 and 12 show the results of cycles of stress at and below the endurance limit. The effect of such "understressing" is to lengthen the subsequent life at higher stresses, and so it seems safe for the designer to ignore their effect. Fig. 13 shows the effect of a continuously modulated amplitude which one would expect to combine the characteristics of both ascending and descending sequences of loading and hence give a value for very nearly unity. This is seen to be the case.

From this experimental evidence it is clear that if

Figs. 9–13 Some experimental results on mild-steel specimens obtained at Nottingham University. These specimens were fatigued to investigate Miner's law of cumulative damage. This law implies that materials have a capacity to stand only so much damage and that failure occurs when the cumulative effects attain that capacity. If the law were true $\Sigma \frac{n}{N}$ would be unity at failure. The experiments indicated that the law is optimistic.

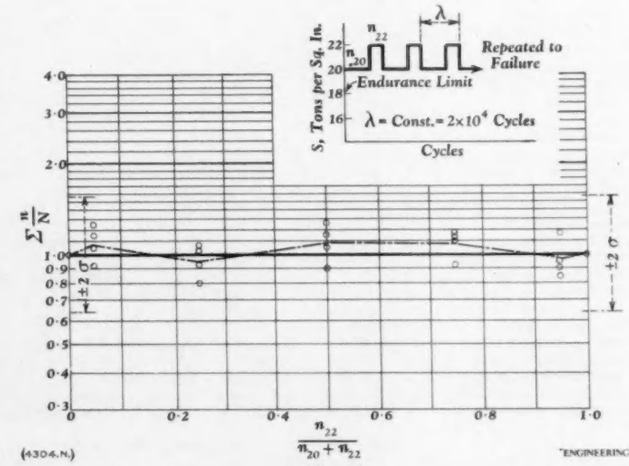

Fig. 13

TABLE III.—*Values of* $\Sigma \frac{n}{N}$

	$\Sigma \frac{n}{N}$		
	Min.	Max.	Mean
Alloy steels, ascending loads ..	0·71	1·66	1·12
" " descending loads ..	0·57	0·86	0·73
Aluminium alloy, ascending loads	0·92	1·77	1·48
" " descending loads	0·56	0·96	0·77

TABLE IV.—*Table of Design Data. Life of* 0·53 *Year*

Load in tons (from Fig. 16)	$n \times 10^6$ (from Fig. 16)	Stress tons per sq. in. A = ½ sq.in.	N (from Fig. 15)	$\frac{n}{N}$
¼	4	1	10^9	Negligible
1½	3·2	3	3×10^8	"
2¼	3·6	5	$1·3\times10^7$	"
3¼	3·4	7	$1·2\times10^6$	0·003
4¼	1·0	9	$2·0\times10^5$	0·05
5¼	1·0	11	$4·6\times10^4$	0·22
6¼	0·6	13	$1·1\times10^4$	0·55
7¼	0	15	4×10^3	0
8½	0·05	17	$1·6\times10^3$	0·31
				$\Sigma \frac{n}{N} = 1·13$

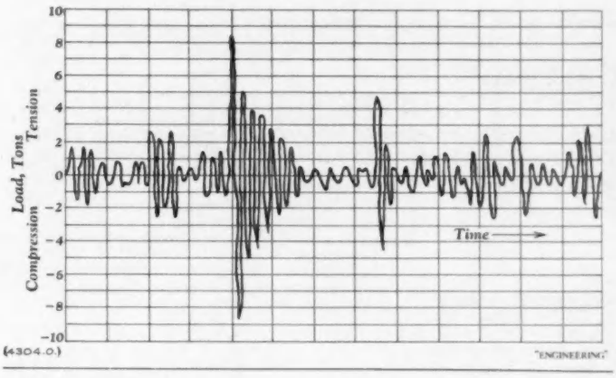

Fig. 14 (left) Hypothetical load sequence for a simple member which is to be made of a light alloy, the fatigue properties of which are shown in Fig. 15 (below). The design problem is examined in the text.

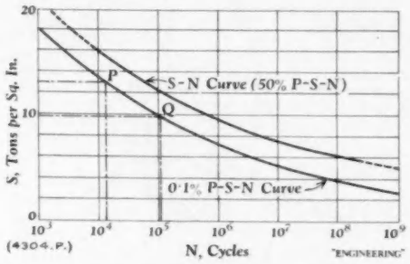

Fig. 15 Fatigue curve for an aluminium alloy.

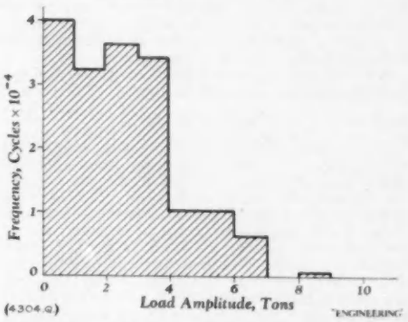

Fig. 16 The load sequence of Fig. 14 re-drawn as a load spectrum to show the frequency of occurrence of each load level. This is used as a basis for designing the component by a modified cumulative damage law.

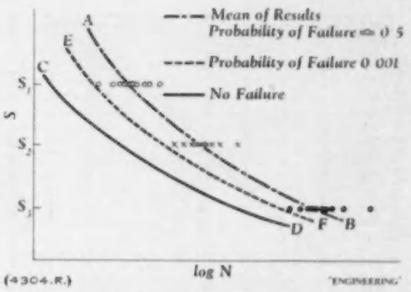

Fig. 17 Typical experimental results of fatigue testing at three values of stress, and three S-N curves appropriate to three values of probability of failure.

the designer is to produce a safe structure he must adopt a value for $\Sigma \frac{n}{N}$ which is somewhat less than unity. Based on the results which are at present available, a value of $\Sigma \frac{n}{N} = 0{\cdot}6$ seems to be reasonable but it must be emphasised that much more work is still required to be done with different alloys and particularly with notched specimens and finished components.

So far the values for N have been considered to be the expected life at the relevant stress level. If this is read from an S-N curve then it will give a value corresponding to 50 per cent. chance of failure. From the point of view of safety it is essential to choose values which correspond to a much smaller chance of failure; such as one in a thousand or one in ten thousand. A graph corresponding to a one in a thousand chance of failure is shown in Fig. 15 (labelled 0·1 per cent. P-S-N Curve) and its position depends on the scatter of the test results. It is this curve which should be used to give values of N for design purposes. Its exact nature will be discussed later when dealing with the statistical aspects of the problem.

DESIGN EXAMPLE

A simple design example will now be given which will bring out the relative points more clearly. A hypothetical load sequence is given in Fig. 14 for a simple member which is free from stress raisers and is subject to direct stress only. It shows the variation of the amplitude of the oscillating load over a period of time—it is assumed that the complete sequence is known or can be estimated for one year's operation. It is required to design a part to last five years with a probability of failure of 0·1 per cent. (i.e., one in a thousand) from an aluminium alloy the fatigue curve of which is given in Fig. 15. In Fig. 16 the load sequence has been re-drawn in the form of a load spectrum so that the number of cycles per annum at each load is given. The law $\Sigma \frac{n}{N} = 0{\cdot}6$ will be used.

To find the cross sectional area A of the member we must proceed as follows: Note that the load values on the load spectrum are approximately half the stress ordinates on the fatigue curve and, therefore, as a first approximation, assume that A = ½ sq. in. and draw up the table shown (Table IV) from the data given in Figs. 15 and 16. It is seen that if A = ½ sq. in. the member will last for only 0·53 year, instead of the five years required. A glance at Table IV shows that the 13 tons per sq. in. stress is predominant and absorbs about 50 per cent. of the life of the component. As a second approximation adjust this stress to give the required increase in life. The life at a stress of 13 tons per sq. in. has to be increased from $1{\cdot}1 \times 10^4$ cycles when A = ½ sq. in. to $1{\cdot}1 \times 10^4 \times \frac{5}{0{\cdot}53} = 1{\cdot}04 \times 10^5$ cycles. In Fig. 15 point P represents the condition when A = ½ sq. in. and $N = 1{\cdot}1 \times 10^4$ cycles; point Q represents the required condition when $M = 1{\cdot}04 \times 10^5$ cycles. The stress is very nearly 10 tons per sq. in. Therefore, the new $A = \frac{1}{2} \times \frac{13}{10} = 0{\cdot}65$ sq. in. Table IV is then re-worked with A = 0·65 sq. in. giving Table V. $\Sigma \frac{n}{N}$ is now equal to 0·157 and the component will last for $\frac{0{\cdot}6}{0{\cdot}157} = 3{\cdot}8$ years. A further approximation worked in exactly the same manner as previously will usually give a satisfactory value for A. In this case a value of A = 0·69 sq. in. will give a component life of 5·4 years. Note that a tenfold increase in life has been obtained by approximately halving the stress.

In working the above simple example the following information was required: (1) the complete load spectrum for the member; and (2) the complete fatigue curve for the material together with a measure of the scatter in results to be expected. In the load sequence shown only oscillating loads with zero mean stress were applied. This is rarely the case in practice and usually allowance must be made for the changes in mean stress as well as in the amplitude of fluctuation. Many more laboratory tests with mean stresses other than zero need to be made before design rules can be formulated with confidence. The best that can be suggested at the present time is to apply Miner's Law using values of N read from fatigue curves with the relevant mean stress. In this case the load sequence must be analysed to give a series of load spectra each referring to a particular mean stress.

Furthermore there is obviously going to be some difficulty in obtaining the load spectrum on a component before it is even designed, but a useful guide can be obtained by recording the load sequences on similar components which are already in use. This type of research is being carried out in connection with aircraft but it needs extending to other fields.

APPLICATION OF STATISTICAL METHODS

In the example worked the fatigue curve for the material was adequate since the component was subjected to direct stress and no stress raisers were present. If, however, one is considering a complex component, such as the spar of an aeroplane wing, ideally the fatigue curve for the component is required, or even that of the completed wing if the final assembly affects the load distribution in the spar. The expense incurred in testing such large components is prohibitive and some compromise has always to be made. The best that can be done is to inspect the load spectrum that it is anticipated the component will have to withstand, select the load which predominates and measure the life of the prototype components at that load. It is suggested that the best procedure is then to assume that the shape of the fatigue curve for the complete component is similar to that for notched specimens made from the same material. The reliable assessment of a few results presents formidable difficulties, however, and the subsequent sections of this paper give as simply as possible the basic statistical analysis necessary to use effectively, from the point of view of design, the results obtained from tests on a few prototype components.

Fig. 17 is taken to represent a typical set of

TABLE V.—*Revised Table of Design Data. Life of 3·8 Years*

Load in tons	$n \times 10^4$	Stress tons per sq. in. A = 0·65 sq. in.	N	$\frac{n}{N}$
½	4	0·8	10^9	Negligible
1½	3·2	2·6	7×10^8	0·0005
2½	3·6	3·9	7×10^7	0·005
3½	3·4	5·4	$7{\cdot}5 \times 10^6$	0·005
4½	1·0	6·9	$1{\cdot}4 \times 10^6$	0·007
5½	1·0	8·5	3×10^5	0·033
6½	0·6	10·0	9×10^4	0·067
7½	0	11·5	3×10^4	0
8½	0·05	13·1	$1{\cdot}1 \times 10^4$	0·045
				$\Sigma \frac{n}{N} = 0{\cdot}157$

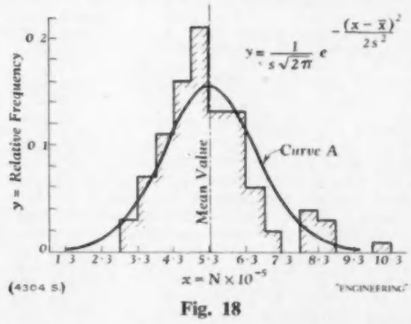

Fig. 18

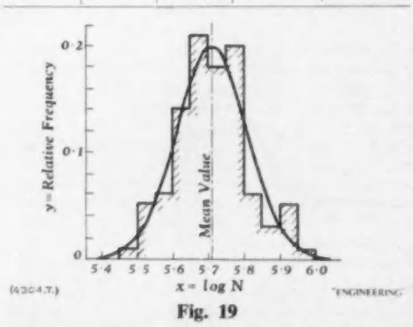

Fig. 19

Figs. 18 and 19 Results of fatigue experiments recorded in Table II presented as a histogram and showing the location of the Gaussian curve. The abscissa in Fig. 18 is the number of cycles to failure; in Fig. 19, where the Gaussian curve fits the data better, the abscissa is the log of the cycles.

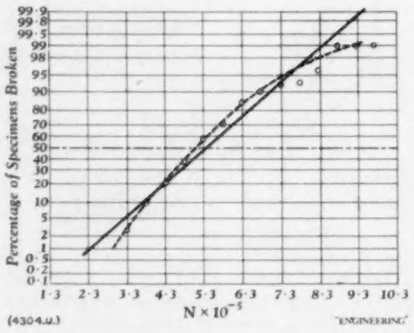

Fig. 20

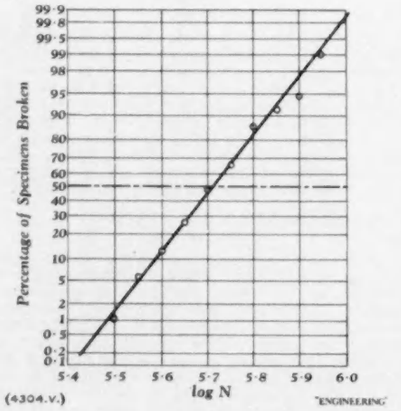

Fig. 21

Figs. 20 and 21 Curves of cumulative frequency plotted on arithmetical probability scales. The abscissa of Fig. 20 is the number of cycles to failure; in Fig. 21 it is the logarithm of the cycles and the curve fits the experimental results better. The "lognormal distribution" is therefore used as the basis of design against fatigue.

experimental results at three different stress levels. The curve AB is drawn through the mean of the results and CD represents the limit to the left of which there is no chance of failure. AB cannot be used as a basis for design since, if it were, approximately 50 per cent. of the components would fail before they had attained their design life; that is, curve AB corresponds to a failure probability of roughly 0·5. On the other hand, the life given by curve CD is only a small fraction of that given by AB (the abscissa is a logarithmic scale) and might represent such a low stressing of the part that any design based on it would be unsuccessful on account of its weight. Lying between AB and CD, curve EF represents a failure probability of, say, 1 in 1,000 and, if this failure rate is regarded as tolerable, it may be used as a basis for design. Curves such as

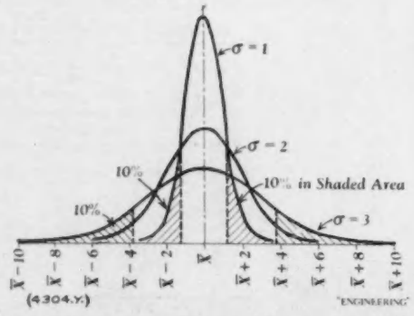

Fig. 22 Comparison of different frequency curves having standard deviations of 1, 2 and 3. The chances of an experimental figure falling within a given range equals the ratio of the area under the frequency curve over the range considered to the whole area under the curve.

TABLE VI.—Values of $x = \log_{10}N$ in Order of Magnitude

5·45 to 5·50	5·48	1
5·50 to 5·55	5·501 5·505 5·539 5·541 5·542	5
5·55 to 5·60	5·567 5·567 5·574 5·576 5·582 5·595	6
5·60 to 5·65	5·604 5·611 5·612 5·613 5·613 5·624 5·626 5·629 5·632 5·634 5·635 5·641 5·641 5·647	14
5·65 to 5·70	5·662 5·663 5·665 5·668 5·668 5·670 5·674 5·675 5·676 5·679 5·681 5·681 5·686 5·692 5·692 5·693 5·693 5·693 5·696 5·697 5·699	21
5·70 to 5·75	5·700 5·702 5·705 5·705 5·705 5·707 5·710 5·716 5·718 5·719 5·720 5·736 5·737 5·740 5·740 5·741 5·748 5·749	18
5·75 to 5·80	5·751 5·752 5·752 5·751 5·758 5·761 5·769 5·769 5·773 5·774 5·774 5·775 5·776 5·782 5·786 5·787 5·787 5·793 5·799 5·798	20
5·80 to 5·85	5·800 5·802 5·805 5·811 5·828 5·844	6
5·85 to 5·90	5·862 5·892 5·896	3
5·90 to 5·95	5·901 5·917 5·922 5·924 5·942	5
5·95 to 6·00	5·997	1
	Total ..	100

these will be called P-S-N curves where P stands for probability. In Fig. 17, AB is the P-S-N curve for P = 0·5, EF for P = 0·001 and CD for P = 0. An S-N curve is statistically meaningless unless the probability of survival (and hence of failure) at points on the curve is specified. It is with the calculation of design stresses from experimental results to satisfy a specified probability of failure that the following paragraphs are concerned.

Before proceeding with the analysis of the problem various statistical terms will be defined. The mean of m values of a variable x is given by $\frac{x_1 + x_2 \ldots + x_m}{m}$ and is denoted by $\bar{x}$. If it were possible to make an infinite number of tests the mean value obtained would be the true mean denoted by $\bar{X}$. In general, the experimental mean $\bar{x}$ obtained from a finite number of tests is not equal to the true mean, although obviously the larger the number of tests carried out the nearer the value of $\bar{x}$ should be to $\bar{X}$. When considering the mean value for the life of a number of nominally identical specimens which have all been tested under the same fatigue conditions it will be shown later that it is best to use $x_i = \log N_i$ where N_i is the number of cycles to failure.

The other important statistical definition is standard deviation. If x_i is the ith value of m experimental results the mean of which is $\bar{x}$, then the scatter in these results is estimated by calculating the variance defined as $\frac{1}{m-1}\sum_{i=1}^{m}(x_i - \bar{x})^2$. The square root of the variance is called the standard deviation s. (This may be regarded as approximately equivalent to the radius of gyration of the experimental points about their mean value.) In the same way that $\bar{x}$ differs from $\bar{X}$ when $\bar{x}$ is based on a finite number of experimental values, so will s the experimental standard deviation differ from σ the true standard deviation.

Recapitulating, the notation is as follows:

$\bar{x}$ = mean value based on a finite number of results;
$\bar{X}$ = true mean value based on an infinite number of results;
s = standard deviation based on a finite number of results;
σ = true standard deviation based on an infinite number of results.

DISTRIBUTION OF FATIGUE TEST RESULTS

Table II gives the lives in cycles obtained from 100 polished specimens tested at the same stress level. The results have been arranged in order of magnitude, each row of figures being those results lying within consecutive intervals of 50,000 reversals. If now the number of reversals to failure is plotted horizontally and the number of specimens which fracture in any given interval is plotted vertically at the appropriate position on the abscissa the diagram obtained is as shown shaded in Fig. 18. Such a diagram is called a histogram, and the boundary of such a figure may be approximated by a smooth curve. A curve which has been found to give an adequate fit to statistical data drawn from many sources is the Gaussian or Normal curve given by the equation

$$y = \frac{A}{s\sqrt{2\pi}} e^{-\frac{(x-\bar{x})^2}{2s^2}} \quad . \quad . \quad (1)$$

where A is a constant.

The general shape of this function is given by curve A in Fig. 18. It is symmetrical about the mean value $\bar{x}$ and approaches the x axis asymptotically to the left and right of the mean (i.e., $y = 0$ when $x = \pm\infty$). It is clear that the histogram given in Fig. 18 is not well approximated by the appropriate normal curve. A much closer approximation is obtained if the logarithm of the number of reversals to fracture is taken as the variable. The logs of the results in Table II are listed in Table VI and the related histogram is shown in Fig. 19.

The consideration of this aspect may be augmented by the use of arithmetical probability paper. The percentage of specimens which break before a specific value of N or log N is reached is called the

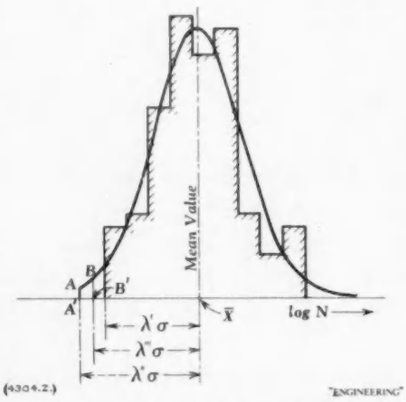

Fig. 23 Truncated distribution which ignores extreme values.

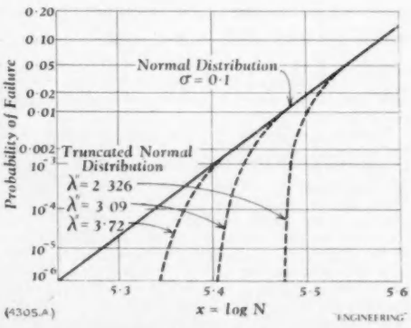

Fig. 24 Effects of using a truncated normal distribution. The probability that extreme results will occur is decreased slightly.

cumulative percentage or cumulative frequency. The scale intervals on arithmetical probability paper are proportioned so that if the distribution is of normal form the cumulative frequency when plotted against life will be linear. This probability paper can, therefore, be used to check the normality of experimental results. In Figs. 20 and 21 the cumulative frequency curves together with the test results have been plotted on probability paper on a basis of N and log N, respectively. The cumulative frequencies corresponding to the normal distribution curves shown in Figs. 18 and 19, are straight lines and the actual percentage of breakages obtained before various values of life are distributed about these lines. It is clear that the agreement is very much better in Fig. 21 than in Fig. 20. This confirms the general conclusions of other workers and it is suggested, therefore, that if a Gaussian distribution is assumed, then log N and not N should be used as the basic variable for statistical analysis regarding fatigue life. Such a curve is termed lognormal. A different distribution function, proposed by Weibull,[15] which also gives a good fit to the results of Table VI, will be discussed later.

It should be emphasised that the distribution of life as calculated by these methods will only be applicable to the stress level at which the tests have been carried out. In general, the life distributions at other stress levels will not be the same, and if a complete P-S-N curve is required it is necessary to carry out tests at a number of stress levels. By consideration of tests on a similar material or components, it may sometimes be justifiable to assume that the life distribution is independent of stress (or dependent on stress in a known way), in which

case tests need be carried out at rather fewer stress levels. For an infinite population the normal equation is:

$$y = \frac{A}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\bar{x})^2}{2\sigma^2}} \quad . \quad . \quad (2)$$

where for fatigue $x = \log N$.

The value obtained for the standard deviation σ depends upon how widely the results are distributed about the mean value. If the distribution is small, then σ is small, and conversely if the scatter is large σ will be large (see Fig. 24). Furthermore, supposing the standard deviation is σ for an infinite population of mean $\bar{X}$, then if instead of considering each result individually the results were divided into groups each containing q results and the mean of each group plotted, then the true standard deviation of the second plot would be $\frac{\sigma}{\sqrt{q}}$. Another important characteristic of the normal distribution is concerned with the probability of any result lying within a certain range relative to the mean. The area of a histogram between any two values of x is proportional to the percentage of the experimental results which lie between these two values, and the area under a frequency curve is similarly representative. If in equation (2), A is made equal to unity then the area under the curve becomes equal to unity (or 100 per cent. say), i.e.,

$$\int_{-\infty}^{\infty} \frac{e^{-\frac{(x-\bar{X})^2}{2\sigma^2}}}{\sigma\sqrt{2\pi}}\, dx = 1$$

while

$$\int_{x_1}^{x_2} \frac{e^{-\frac{(x-\bar{X})^2}{2\sigma^2}}}{\sigma\sqrt{2\pi}}\, dx \quad . \quad . \quad . \quad (3)$$

represents the proportion of results lying between x_1 and x_2.

It is simple and convenient to measure x_1, x_2, etc., as a number of standard deviations from the mean. Thus writing $x_1 = \bar{X} + \lambda_1\sigma$, $x_2 = \bar{X} + \lambda_2\sigma$ and putting $t = \frac{(x-\bar{X})}{\sqrt{2}\,\sigma}$, (3) becomes

$$\int_{\frac{\lambda_1}{\sqrt{2}}}^{\frac{\lambda_2}{\sqrt{2}}} \frac{e^{-t^2}\,dt}{\sqrt{\pi}} = \int_{0}^{\frac{\lambda_2}{\sqrt{2}}} \frac{e^{-t^2}\,dt}{\sqrt{\pi}} + \int_{0}^{\frac{\lambda_1}{\sqrt{2}}} \frac{e^{-t^2}\,dt}{\sqrt{\pi}} \quad . \quad . \quad . \quad (4)$$

where t is dimensionless.

It is not possible to represent the integral $I = \int_0^{\frac{\lambda_1}{\sqrt{2}}} \frac{e^{-t^2}\,dt}{\sqrt{\pi}}$ in finite form but it has been tabulated for all values of λ_1 (see for instance Hald[11]), and it is from such tables that the probability figures shown in Table VII have been calculated. From this table it can be seen, for example, that 80 per cent. of the experimental points covered by the normal distribution curve will lie between $x = \bar{X} + 1{\cdot}282\sigma$ and $x = \bar{X} - 1{\cdot}282\sigma$ (i.e., $\lambda = \pm 1{\cdot}282$). Since the curve is symmetrical about $\bar{X}$ it follows that 10 per cent. of the results will lie in the range $-\infty < x < \bar{X} - 1{\cdot}282\sigma$ while 10 per cent. lie in the range $\bar{X} + 1{\cdot}282\sigma < x < \infty$; see Fig. 24.

TABLE VII.—Calculated Probability Figures

2I = Area between $\bar{X} - \lambda\sigma$ and $\bar{X} + \lambda\sigma$	λ	Value of x	Chance of obtaining a value less than $\bar{X} - \lambda\sigma$	
0	0	$\bar{X}$	1 in 2	or probability $p = 0{\cdot}5$
0·8	1·282	$\bar{X} - 1{\cdot}282\,\sigma$	1 in 10	$p = 0{\cdot}1$
0·95	1·96	$\bar{X} - 1{\cdot}96\,\sigma$	1 in 40	$p = 0{\cdot}025$
0·98	2·326	$\bar{X} - 2{\cdot}326\,\sigma$	1 in 100	$p = 0{\cdot}01$
0·996	2·878	$\bar{X} - 2{\cdot}878\,\sigma$	1 in 500	$p = 0{\cdot}002$
0·998	3·09	$\bar{X} - 3{\cdot}09\,\sigma$	1 in 1,000	$p = 0{\cdot}001$
0·999	3·291	$\bar{X} - 3{\cdot}291\,\sigma$	1 in 2,000	$p = 0{\cdot}0005$
0·9998	3·721	$\bar{X} - 3{\cdot}721\,\sigma$	1 in 10,000	$p = 0{\cdot}0001$
0·9999	3·8906	$\bar{X} - 3{\cdot}8906\,\sigma$	1 in 20,000	$p = 0{\cdot}00005$
0·999998	4·7534	$\bar{X} - 4{\cdot}7534\,\sigma$	1 in 10^6	$p = 0{\cdot}000{,}001$

TABLE VIII.—Effect of Truncation on the Deduced Probabilities of Failure

λ''	Probability of failure assuming normal distribution	Probability of failure assuming a normal distribution truncated at $\bar{X} - \lambda''\sigma$ (calculated to 4 sig. figures)				
		$\lambda'' = 2{\cdot}326$	$\lambda'' = 3{\cdot}09$	$\lambda'' = 3{\cdot}721$	$\lambda'' = 4{\cdot}265$	$\lambda'' = 4{\cdot}753$
1·282	0·1	0·09090	0·09910	0·09991	0·09999	0·1000
2·326	0·01	0	0·009009	0·009901	0·009990	0·009999
3·09	0·001	0	0	0·0009001	0·0009900	0·0009990
3·72	0·0001	0	0	0	0·00009000	0·00009900
4·265	0·00001	0	0	0	0	0·000009000

From the point of view of design it is clearly only the lower area which need be considered because it represents the weak or short-lived specimens. Put into words, Fig. 24 implies that if the mean life of a large number of tests is $\bar{X}$, $\left\{\bar{X} = \frac{1}{m}\sum_{i=1}^{m} \log N_i\right\}$ then there is a 0·1 or 10 per cent. probability that a specimen will fail at a life less than that given by $\log N = \bar{X} - 1{\cdot}282\sigma$; in a similar manner it can be shown that 0·01 or 1 per cent. of all specimens will not survive a life given by $\log N = \bar{X} - 2{\cdot}326\sigma$. These values of λ, i.e. 1·282, 2·326, etc., are known as standard normal deviates.

Obviously the Gaussian distribution cannot hold for all fatigue life results since it extends to $x = -\infty$ and in practice the minimum application of load that can be applied is $\frac{1}{4}$ reversal, the logarithm of which is negative but finite. The importance or otherwise of this limitation of the Gaussian distribution depends upon the average life of the components under consideration and the probability of failure acceptable in the design. Practical evidence may show that no specimens will break before a life given by, say, $\log N = \bar{X} - \lambda'\sigma$ (*vide* Fig. 17) in which case it might be possible to terminate the Gaussian distribution at $\log N = \bar{X} - \lambda''\sigma$ where $\lambda'' > \lambda'$. This would then be a truncated normal distribution as shown in Fig. 25, where a likely histogram is also illustrated. Whether such a refinement need be adopted will now be considered. If the order of life is large then to modify the complete Gaussian distribution to include only values of, for example, $N > 1{\cdot}0$ is a waste of time. For instance, if the mean life is about 10^6 reversals, and hence $\log_{10} N = 6$, while $\sigma \doteq 0{\cdot}1$ (as in the test results given), then the zero on the log scale is 60σ from the mean, and the theoretical probability of a result occurring at N less than unity is less than 10^{-709}. In the general case illustrated in Fig. 25, the probability of failure at a life below $\log N = \bar{X} - \lambda''\sigma$ is defined as zero, and the probability of failure below the life given at the point B′ ($x = \bar{X} - \lambda''\sigma$) is numerically equal to

$$\frac{\text{Area A′ A B B′}}{\text{Area under curve to the right of A A′}}$$

The effect of any such truncation upon the deduced probabilities of failure is clearly dependent upon the relative values of λ'' and λ'''. This is illustrated in Table VIII.

Except for the cases where the ratio of the mean life to the shortest life is small (when a small value of λ'' can be chosen), or where the demanded probability of failure in design is low (i.e. λ''' is large), the effect of assuming a normal distribution is small indeed and in all cases errs slightly on the safe side.

For example, from the results given in Table VI, $\lambda' = 2{\cdot}3$ and λ'' must be taken greater or equal to this. Fig. 26 then shows the respective probabilities of failure for three values of λ''.

To be continued

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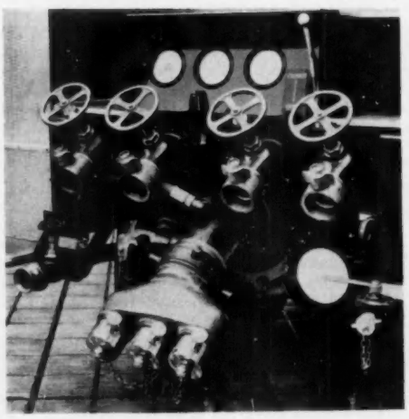

FIRE PUMP FOR THE AUXILIARY FIRE SERVICE

Shown in the accompanying illustration is the heavy-duty, single-stage centrifugal pump, known as Type FN5, which Sigmund Pumps Limited, Team Valley, Gateshead, 11, are supplying for the new fire-fighting tenders of the Auxiliary Fire Service.

The official specification called for an output of 900 gallons per minute against a pressure of 100 lb. per sq. in. The pump is driven directly from the 100 h.p. engine of the tender (a Bedford chassis) at 3,000 r.p.m. and will achieve its full output of 900 gallons per minutes on a 10 ft. lift working with 5½ in. suction hose. The pump can be primed on suction lifts up to 25 ft. in 19 seconds by means of a horizontally opposed piston-type priming pump, actuated by a friction drive from the main pump shaft and brought into operation by a simple pull on a lever. Each of the twin discharge branches is fitted with a breeches piece, so that four hose connections are available. Each has its own screwdown valve, provided with a standard instantaneous coupling. There is also a 6 in. full-bore outlet, fitted with a non-return valve, for use in relay work in conjunction with 6 in. hose or piping. The pump can also be used for projecting foam, provision being made on the suction and delivery for connecting a multi-jet foam inductor without the need for adaptors.

The drive from the engine of the vehicle is through a transfer gearbox and transmission shaft, which is connected to the pump spindle by a Hardy-Spicer coupling. When the tender is on the road, the engine is sufficiently cooled by the radiator, but additional cooling is necessary when the pump is being driven for long periods, and is provided by means of a heat exchanger fitted under the radiator.

Book Reviews

INVESTIGATION BY RADIATION

A Further Handbook of Industrial Radiology. By members of the Non-Destructive Testing Group of the Institute of Physics. Edited by W. J. WILTSHIRE. *Edward Arnold (Publishers), Limited, 41 Maddox-street, London, W.1.* (50*s.*)

A Further Handbook of Industrial Radiology is a collection of papers in which various methods, means, and aspects of applying high-energy radiation for the investigation of materials are discussed. Though the basic principles which were given in the *Handbook of Industrial Radiology* (1944) hold good now as before, advances have been made in the development of new processes and methods. There are good reasons why the radiologist in industry should be kept informed concerning the possibilities of improving his work which, in many cases, appears to be satisfactory merely because there are no corresponding standards of comparison.

In industry, the objects to be examined by means of radiography are so varied in dimension, shape, and material that there is no general rule for the selection of the best means and method for any given case. In principle, the radiologist can choose from a range of X-ray generators and radioactive isotopes, films, screens, arrangements, and exposure times (some methods available operate without a film); any choice, within reason, will yield some sort of radiograph, but it is not so easy to be sure that there is no alternative which would provide more information regarding the object concerned, or which would have been more convenient in its execution.

It is one of the merits of the new *Handbook* that each of its chapters has been written by an author who is particularly familiar with the subject of his contribution. It is, therefore, unlikely that any practising radiologist could peruse the book without encountering a clue which pertains in some way to his own special problems. The list of contents may give the impression that many of the chapters are of interest only to a limited number of people who happen to be engaged in the highly specialised work involved. This is not the case, because every chapter deals with some fundamentals or details of application which, perhaps in modified form, may be employed with advantage in other types of radiographic work.

The new *Handbook* is particularly suitable as a source of ideas for persons who have to overcome a problem in radiography in which the ordinary methods cannot be used, for one reason or another. Such conditions occur, for instance, if the test object has a complicated shape, or limited accessibility. In some cases, little time is available for taking radiographs; in other instances the surroundings have to be kept at a low radiation level because the progress of work must not be interfered with. In all industrial applications, the cost of equipment and operation is one of the main factors that have to be taken into consideration. It is obvious that no book could cater for all combinations of conditions under which radiographs are needed. It is of great advantage, however, to have a book which covers the widest range of applications and from which some elements can be selected and combined to suit a given purpose.

The preface contains a long paragraph which almost apologises for the inclusion of Mr. Rooksby's chapter on X-ray diffraction. Some readers will think that if microradiography comes within the scope of the book, then mere consistency demands the discussion of X-ray investigations on the atomic scale as well. After all, it seems that some types of lattice imperfections, whether they are due to manufacturing procedures or service conditions, have sometimes a greater bearing upon the strength of a structure than voids or foreign inclusions of macroscopic size, the detection of which is still the main target of industrial radiography.

INDUSTRIAL VARIETY

Notes on the Engineering History of Derbyshire. By FRANK NIXON. *Derbyshire Archaeological Society (Mr. K. Mantell), Starth House, Tansley, Matlock, Derbyshire.* (2*s.* 9*d.*)

Derbyshire probably has as varied an industrial history as any county in Great Britain. Lead and iron ores, coal and limestone, abundant and easy of access, were exploited at an early date, and the streams and rivers of the county provided a basis for numerous other industrial undertakings, such as brewing, dyeing and textile manufacture. From the needs of all these industries sprang the demand for better transport which led to early canal and railway building, and another natural consequence of the county's varied industrial activities was the development of machine tool and engineering concerns. Some of these activities have ceased, others continue, sometimes in altered form to adapt themselves to the changed needs of the day, and Derbyshire industry still has the variety which has characterised it for centuries.

Because it started its industrial activities so early and operated them so extensively, it is only natural that Derbyshire should have had its full share of pioneers, some of them natives of the county, while others from further afield were attracted by prospects of being able to apply their particular arts and skills. The great civil engineer, Brindley, Outram, the tramway pioneer, and Strutt, whose name is so closely connected with textiles, were all Derbyshire men. Of the "outsiders" it is only necessary to mention George Stephenson, whose hand can be seen in many Derbyshire industrial undertakings still in operation, and Arkwright, who found the water power of the county just what he needed for his great cotton mills.

The activities of these men and many others, both famous and obscure, combined to produce an industrial scene in Derbyshire which is of considerable interest, and which has attracted the attention of several writers. While information is available, however, it is scattered, and the present publication, which originated as a paper given before the Derbyshire Archaeological Society, serves as a good general introduction to the county's industrial history. It is well illustrated, and as all worthwhile historical accounts should be, is copiously annotated, source references being given for those who wish to pursue the subject further.

PRACTICAL INTRODUCTION

The Diesel Locomotive. By R. L. ASTON. *Thames and Hudson, Limited, 30 Bloomsbury-street, London, W.C.1.* (12*s.* 6*d.*)

Intended for the large number of drivers and maintenance personnel on railways and in industry now coming into contact with Diesel motive power for the first time, often with brief and scanty training, this book keeps to its title and does not attempt to deal with the types of engines, transmissions and auxiliaries found in the numerous railcars of British Railways. But it does not suffer thereby; and the clarity and simplicity of the writing, and the sense of proportion of the author, as to what can be covered in such a book and what should not be attempted, have resulted in an extremely good small introductory work which might well be used as a text-book, or as a recognised addition to any specific training scheme in force.

The effective descriptions of oil-engine principles and construction are supplemented by others on engine control; locomotive auxiliaries such as brakes; safety measures; mechanical, electric and hydraulic transmission systems; and operating faults and maintenance. There is not that defect found in many books—"packing" with makers' information on fuel-injection equipment. In only one direction is the book lacking, and that is in relation to engine auxiliary systems. Future editions might well have diagrams, and descriptions, in the author's succinct and unemotional style, of cooling water and lubricating oil systems, and of belt and gear drives to engine-driven auxiliaries, for often these are responsible for more than half of all defects.

As Mr. John F. Alcock remarks in a foreword to the book: "The development of the Diesel locomotive over the past twenty-five years has been phenomenal, but the next few years will see great changes and a considerable quickening of the pace . . . . More powerful and greater numbers of Diesels of various sizes and types will appear on our railways and a much better understanding of them will be essential if we are to obtain the tremendous advantages which the Diesel locomotive offers."

ELECTRICAL CONTACT

The Physics of Electrical Contacts. By F. LLEWELLYN JONES. *Oxford University Press, Amen House, Warwick-square, London, E.C.4.* (35*s.*)

The literature of a subject over half a century old inevitably contains many conflicting statements. Even relatively recent work suffers from the confusion resulting from the failure of earlier experimenters to appreciate all the factors influencing their results and Professor Jones has done a great service in presenting the subject of electrical contacts clearly and concisely. His book also contains an account of recent researches in his own laboratories at Swansea. It is addressed primarily to the physicist and the electrical engineer interested in the fundamentals of the subject and is not in any sense a handbook of contact design. Indeed, both the practical engineer and also the physicist will be disappointed by the total absence of any quantitative data from which to start calculations. Nevertheless, no contact designer can afford to remain in ignorance of the contents of the book.

The first four chapters are devoted to a critical account of the work on fine (= arcless) transfer up to 1955 and contain much material in common with the author's *Fundamental Processes of Electrical Contact Phenomena* (H.M. Stationery Office, 1953). Chapters 5, 6 and 7, on the other hand, contain new material, a great deal of it unpublished, on the shapes of liquid metal bridges, the properties of contact metals at high temperatures and the mechanism of fine transfer. The last two chapters, on arc erosion and on surface film effects, seem rather short in comparison with the rest of the book, considering their importance.

The new work described in chapter 6 concerns the shape and size of liquid metal bridges. After discussing the factors which must be taken into account, including surface tension and electrodynamic forces, the method of calculation is outlined. It is a pity that no direct comparison is made with the actual results of experiment, especially as elsewhere (*Z. Phys.*, vol. 147, page 43) the author has claimed that the calculations agree with measurements. The experiments described here appear to have been limited to visual appreciation and a measurement of rupture voltage. From the latter it appears that bridges of certain metals, including platinum, become unstable before actual boiling is reached.

Illuminating results of transfer measurements

made by radioactive tracer technique are described. The technique is a great advance on previous investigations as it enables the gross transfer in both directions to be assessed and not only the net transfer from positive contact to negative. It has been shown that the whole bridge is involved in the transfer process. Such a result lends a great deal of support to the Bühl droplet theory of transfer (1926). According to this, the bridge disrupts into positively charged metal droplets which are carried down the electric field between the contact faces. In the light of the facts, it is no longer surprising that the transfer in platinum is in the opposite sense to that expected on the basis of thermo-electric asymmetry in the bridge. It is a pity that no quantitative data are given for the amounts of transfer actually measured.

However, it is doubtful whether publication in book form is the most desirable means of bringing new work to the attention of other interested workers. In the first place, the form excuses the author from giving all the data essential to establish his contentions and, in the second place, the delay in publication makes duplication of effort a serious risk. It is much to be hoped that Professor Jones and his associates at Swansea will publish their results in greater detail as soon as possible.

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NEW BOOKS

Guide to I.G.Y. International Geophysical Year 1957-8. *Methuen and Company, Limited*, 36 *Essex-street, London, W.C.2.* (2*s.* 6*d.*)

This illustrated booklet comprises contributions by members of the British National Committee for the International Geophysical Year, with a foreword by the Chairman, on the I.G.Y. programme, solar activity, cosmic rays, the ionosphere, aurora and airglow, geomagnetism, meteorology, glaciology, longitudes and latitudes, oceanography, seismology, rockets, the Skylark high-altitude research rocket, the satellite programme, and suggestions for some simple observational work. An I.G.Y. calendar is included.

Jet Engine Manual. By E. MANGHAM and A. PEACE. Second edition. *George Newnes, Limited, Tower House, Southampton-street, London, W.C.2.* (10*s.* 6*d.*)

The first edition, published in 1955, has been revised to keep up with the rapid technical advances in turbine aero engines. Intended for men engaged in the operation and maintenance of such engines, it is in the form of question and answer, and covers the construction, mechanical and functional details of the turbojet and propeller turbine; terms and abbreviations in current use; fuel systems; lubrication; starters; controls and operation and engine testing; installation; trouble-shooting and inspection; atmospheric tables, definitions and conversion factors. A rather brief index is included.

Physics. By S. G. STARLING and A. J. WOODALL. Second edition. *Longmans, Green and Company, Limited*, 6 *and* 7 *Clifford-street, London, W.1.* (55*s.*)

Designed primarily to provide a consistent and comprehensive course in physics—general, heat, light, sound and electricity—from "intermediate" standard up to the "pass" and general honours degrees of representative British universities, the first edition of this text-book has been found useful in industrial research laboratories and information centres. With this in mind, the authors have thoroughly overhauled the tabulated data and the index in this second edition. Major changes in the revised edition include the introduction of a short section on rotatory motion, improved methods of handling problems on alternating currents, the addition of appendices on vacuum physics, electronic apparatus, and the M.K.S. system of units. To encourage students in further reading, lists of references are given at the end of each chapter as well as a general bibliographical appendix. A generous selection of problems and answers taken from University of London examination papers is included.

Guided Weapons. By ERIC BURGESS. *Chapman and Hall, Limited*, 37 *Essex-street, London, W.C.2.* (25*s.*)

In this general survey of the guided-weapons scene, the author has aimed at introducing the reader to the historical and technical fundamentals on which guided weapons are based, and to underlining the difficulties that have delayed their production. The aspects covered include systems and missiles, propulsion and propellants, guidance and control, testing, ground-to-air missiles, air-launched missiles, ground to ground missiles, production and development. A general bibliography is included as well as a list of references at the end of each chapter.

Metrology of Gage Blocks. Proceedings of a Symposium on Gage Blocks held at NBS on August 11 and 12, 1955. National Bureau of Standards Circular 581. *Superintendent of Documents, U.S. Government Printing Office, Washington* 25, *D.C., U.S.A.* (1.50 dols.)

The Symposium on Gage Blocks was held to permit the exchange of ideas between the U.S. National Bureau of Standards and manufacturers and users of gauge blocks, for developing better techniques for their manufacture and use. The proceedings comprise 15 papers presented at the Symposium and a very brief discussion on two of the papers. Three papers deal with the metallurgical and physical properties of gauge block materials, there is one paper on the characteristics of gauge-block measuring surfaces—roughness, scratch depth, condition of edges; six papers are concerned with the application of interferometry to gauge blocks and four papers deal with the development of commercial and government standards and specifications.

Bau und Betrieb von Dieselmaschinen. By FRIEDRICH SASS. *Springer-Verlag, Reichpietschufer* 20, *Berlin, W.35.* (75 *D.M.*).

This volume covers the construction of engines of various sizes and types and shows how the characteristics of components are determined in accordance with service requirements. It also offers a full theoretical section, including balancing, torsional vibration and oscillation damping. It has been described as a text-book for students, but it is, in fact, far more than this. Theoretical and practical considerations are developed together, the one illustrating and reinforcing the other. Descriptions of several existing engines of different makes are given in detail.

On the Shelf

By Frank H. Smith

A letter has been sent out by Brian G. Staples from the Reference Library, Ratcliff Place, Birmingham, 1, in which he says "The West Midlands Group of the Reference and Special Libraries Section of the Library Association has decided to compile and publish a guide to library resources in the West Midlands Area. A questionnaire has been drawn up, and a copy is being sent to every public library headquarters, and to every academic and special library which we know to exist in the Five Counties. A few, however, are bound to have been overlooked and if any librarians who read this letter do not receive a questionnaire, perhaps they would be kind enough to contact me at the address given. I shall be glad to let them have a copy."

These collective guides to sources are absolutely invaluable as library tools and my only criticism is that this one does not appear to be a joint effort with Aslib. If it were, there would be far less danger of inevitable omissions.

The National Research Council of Canada, Division of Mechanical Engineering, Ottawa, 2, have hitherto issued Reports in a series with the prefix MR. With No. 6 in this series they have "done a switch" and started (with No. 1) a prefix MER. To put it in a nutshell, MR 6 is now MER 1. "Notes" issued by the department will have the prefix MN.

To the list of trade-sponsored films available for free hire should be added "The Titanium Pigment Story" (British Titan Products Company, Limited, Coppergate, York). A 23-minute film in Eastman colour, it tells, with a commentary by Alvar Liddell, how the pigment is extracted from crude ore and its subsequent use in paint, paper, rubber and, finally, "how titanium oxide makes its contribution to our welfare by improving the appearance of almost everything we live and work with." A big claim by any standards.

The Lamp, the house (prestige? sponsored?) magazine of the Standard Oil Company, 30 Rockefeller Plaza, New York, 20, U.S.A., celebrates, with its latest issue, the 75th anniversary of the company. It is, naturally, an issue with a strongly historical flavour, a flavour I particularly like. In these days when so much of research has an ephemeral value and pages of figures are compiled by computers to be abandoned when they are proved to be incorrect or unsuitable, history gives one a nice, solid, satisfactory feeling. Providing, of course, it is a history of progress.

I am almost daily reminded that one cannot afford to ignore the most unlikely sources when one is seeking information. A short while ago I was asked what make of fuel the Wright brothers used on December 17, 1903. Here, in *The Lamp*, is the answer: it was Standard Oil of course.

Back to one of my hobbyhorses—publicity material. On the whole, brochures, hand-outs and similar publications justify their existence and expense. They seem to have some use for somebody. An item like the *Polyester Handbook* 1957, of Scott Bader and Company, Limited, Wollaston, Wellingborough, Northamptonshire, is good on all counts. It is well produced, generally interesting, technically informative and well illustrated. The sort of handbook, in fact, that a librarian or a polyester-user will keep on his shelf and refer to—with, no doubt, ultimate benefit to Scott Bader. At the other end of the scale, I have a brochure which I cannot, of course, name, that seems to fulfil absolutely no function but useless expenditure. There are photographs of company officials, photographs of the machine shops, photographs of stages of manufacture (which are no different from any other factory's producing the same article) and even a photograph of a storeroom bin. The text is a child's guide to what is happening. It is all done on beautiful glossy paper which makes it all the harder to tear across before throwing in the waste-paper basket.

And talking of publicity matter, the quantity of brochures, duplicated sheets, and "invitations to see us on stand so-and-so" makes it obvious that the Society of British Aircraft Constructors' show is upon us. In passing, I understand that more space than before is being given to guided missiles this year.

There is a quite noticeable increase in the number of books published, or contemplated, on the subject of stress and strain. It is some consolation to know that materials and structures are suffering from the modern way of life nearly as much as humans.

Still they come. New journals announced for 1957 by Academic Press, 129 Queensway, London, W.2, are *Annals of Physics* (monthly), *Information and Control* (quarterly), *Journal of Molecular Spectroscopy* (bimonthly), and *Journal of Ultrasonic Research* (quarterly). Librarians! Look to your budgets.

Soviet News quotes an article in the American journal *Mechanics Illustrated* which reviews a Soviet scientist's ideas for a comparatively inexpensive rocket to the moon. The American says that the United States should therefore take steps to seize the moon before the Russians do so. In an interview, the Russian, Khlebtsevich, stresses that Soviet scientists have nothing to do with building military bases on the moon in order to threaten the United States. All of which, no doubt, will be very reassuring to ordinary folk.

HIGH STRUCTURAL PERFORMANCE

ADVANCED APPLICATIONS OF PRESTRESSING

By A. J. Harris, B.SC.(ENG.), M.I.C.E.*

High specific strength and stiffness, resistance to fatigue, are properties much in demand in structural materials; the further demand for such properties at high temperatures is growing, but difficulty is being experienced in extending the properties of metals to meet these demands. The technique of prestressing provides a radically new response to the problem. By the accident of its invention and development by a civil engineer, prestressing has been confined hitherto to the civil field where, associating high tensile steel with concrete, it has rapidly gained ground over the last 25 years. The basic conception is, however, by no means limited in application to this field and these materials; the following article describes the typical characteristics and behaviour of prestressed materials which, it is claimed, render them of great interest wherever high structural performance is needed.

PRINCIPLES

Prestressing is a technique whereby permanent stresses are applied to a material in a contrary sense to those stresses under load which are most dangerous. Stated thus, the principle does not seem novel. Nor is it. Many classic applications spring to the mind; for example, the over-tensioning of stays to enable them to support compression and the straining of redundant structures to obtain a more favourable distribution of dead-load stresses. Few of these applications, however, are of more than secondary advantage.

On the other hand, the application of the principle to materials of high compressive strength but low tensile strength brings advantages of a totally different order. The principle is here primarily used to enable the material to support high tensile stresses; this it does by inducing a permanent compressive stress in the zones where tension is likely to occur. Again, the principle is not novel; a masonry arch, a brick chimney stack, owe their stability specifically to the fact that tensile stresses under load are masked by compressive stresses caused by the dead-weight of the structure. Gravity, however, is a clumsy and expensive means of exerting force; external thrust applied against abutments is little better. Prestressing as a technique owes its existence to the ability to create locked-up compressive stresses in a structure by the action of tensioned elements of very high tensile strength; such elements are referred to as "tendons."

The significance of the technique lies in the following argument. There are many attractive materials of high compressive strength, for example, ceramics, the various concretes, etc., and these materials are in general chemically inert, of high stiffness and inexpensive; many are also refractory. There also exist other materials of very high tensile strength which are seldom used in structures, either because of the small range of shapes available (e.g., cold drawn steel wires) or because of the excessive strains consequent on a full use of their strength (e.g., glass fibres). Prestressing enables materials of the latter category to be used to endow materials of the former with tensile strength, both being employed to the limits of their respective strengths.

BEHAVIOUR UNDER LOAD

The basic behaviour may be illustrated by the somewhat childish model illustrated in Fig. 1. Imagine a three-legged stool *A* held upside down against the ceiling by a spring *B* exerting a force F; on the stool is hung a weight W. This arrangement is the equivalent of a member of zero tensile strength submitted to a prestressing force F and a tensile load W. If stability as W increases from zero upwards is considered, it is found that:

(*a*) W = 0: the whole of F is carried by the legs; the compressive stress is thus at a maximum at zero load.

(*b*) W = F: the stress in the legs is zero; the force in the spring will have been increased very slightly by the decompression strain in the legs.

(*c*) W > F: the stool comes away from the ceiling, i.e., the structure has "cracked." The strain in the system is now that of the spring.

(*d*) If W is now reduced below F, the stool will return to the ceiling (provided the spring has not been overstressed); in other words, any cracks will close up and the structure will be as before.

A similar model can readily be designed to illustrate behaviour under a bending action; the load is applied horizontally and the spring is eccentric and/or inclined, and may even lie outside the base of the stool. The deflection diagram of both models will be similar to that shown in Fig. 2. The point of marked inflection is common to all prestressed structures; but it is important to note that this point of inflection lies within the elastic range and not at the elastic limit as with the somewhat similar point in mild steel. In consequence, all the usual phenomena of redistribution of load in redundant structures may occur, but without permanent deflections.

The observed characteristics of a prestressed structure can be examined in the light of this idealised model. It will first be noted that problems of elastic compatibility dog the steps of those who endeavour to reinforce intimately one material with another. It was for this reason that reinforced concrete was dismissed some 60 years ago by French mathematicians as an elastic absurdity, and they were correct in so far as attempts to use very high strength steel or very high strength concrete in reinforced concrete have never been successful. In a prestressed structure such problems do not arise, if the range only up to the cracking point is considered, for the two materials, the tensile and compressive, are not constrained, in defiance of their nature, to act together but, on the contrary, act against one another. As the main function of the tendon is to apply a force, the highest possible tensile strength may be sought irrespective of stiffness—indeed, a large extension may be an advantage since it helps ensure the permanence of the prestress against the creep of the compressed material. The critical properties to be examined will be creep losses, specific strength and cost per ton of force. It follows that a material such as glass fibre which potentially has a high tensile strength and small creep loss, but has hitherto been unusable because of a low Young's modulus, immediately becomes interesting.

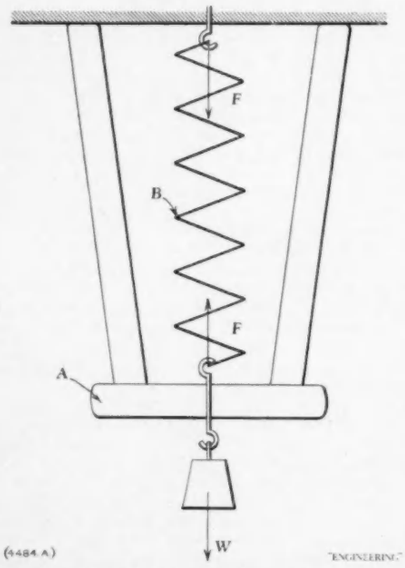

Fig. 1 The principle of prestressing is readily appreciated in terms of a simple "behaviour" model. The model represents a member of zero tensile strength which is submitted to both a prestressing force and a load.

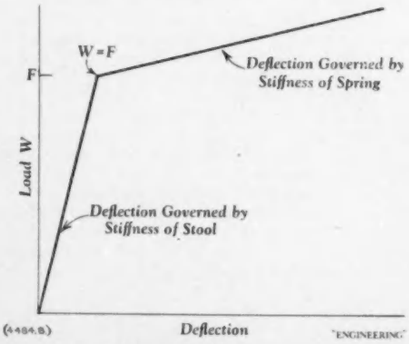

Fig. 2 Load-deflection characteristics of a prestressed member; the point of inflection lies within the elastic range of the compound member, not at the familiar elastic limit.

RUPTURE CONDITIONS

It is clear from the example of the three-legged stool that the rupture strength in tension of the structure is not greater than that of the tendon; in bending the tensile force in the couple is, in general, similarly limited. It is also clear that a tendon of small stiffness may lead to extremely large deflections between the applications of the cracking load and rupture load.

Examination of Fig. 3 will show, however, how the relation between load and deflection at cracking and rupture is under the control of the

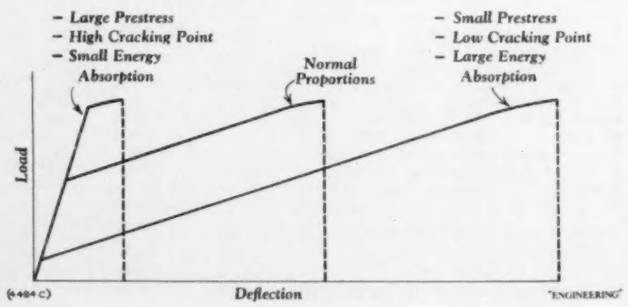

Fig. 3 Effect of varying the stress in the tendon on the load-deflection characteristics of a structure.

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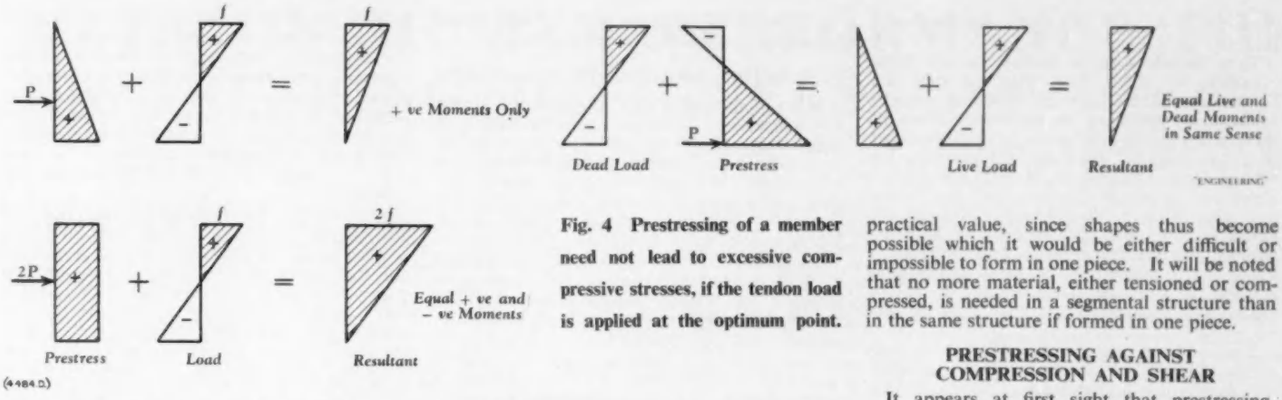


Fig. 4 Prestressing of a member need not lead to excessive compressive stresses, if the tendon load is applied at the optimum point.

designer by varying the section and initial stress of the tendon. If, for example, the tendon be prestressed to the maximum load it will carry, the structure will bear indefinite repetitions of a load just under the cracking load (curve A), but will break in a brittle manner for a load just over. On the other hand, if the tendon is not prestressed at all, the cracking load will be just over zero (curve B); any arrangement between these two limits may be chosen. As a result, the elastic properties of the structure are themselves, as it were, synthetic.

A further aspect may be noted whilst considering rupture. Most materials exhibit a certain amount of creep under load and it will generally be necessary to overstress the tendons to allow for this. If the design range of load is below the cracking load and is never exceeded, the stress in both tendons and compressed material is never higher than immediately after stressing. The operation of applying the prestress is thus a most effective acceptance test and it is found that defects of material are revealed at this stage. This feature is significant in considering factors of safety, as an appreciable part of the factor is required to cover just the risk of inadequate strength of structural material.

When fatigue is considered the significant fact is that the initial strain of the tendon is always large compared to its strain under load. Since, at any rate with high tensile steel, variation of stress is more important in conditions of fatigue than the mean value, prestressing would seem to have possibilities of resisting extensive repetition of load. Such, in fact, has been found in tests of concrete members prestressed by high tensile steel tendons. Fatigue tests are numerous: the following is one of the rare tests which were continued to failure.

A beam, with a static rupture strength of 14·9 ton was submitted to $1{\cdot}32 \times 10^6$ applications of a load of 11·75 ton and finally failed after $2{\cdot}35 \times 10^5$ subsequent applications of 12·5 ton, i.e., 0·84 × static rupture load. The failure was not brittle, but was caused by the rupture of one wire and was detected only by the impossibility of maintaining the load in the testing machine. The remaining sound wires closed up the cracks in the beam, which appeared intact on removal from the test bench. Other tests in the same series indicated that the fatigue limit is closely related to the cracking load; its value would thus seem also to be under the control of the designer.

Due to the lower stiffness after cracking, a prestressed structure has two resonant frequencies, one at load lower than the cracking load, and a very different one for loads higher. It seems then that only a rather curious combination of circumstances could lead to rupture by resonant vibration.

BRITTLENESS

The term brittleness, as normally used, appears to relate to two separate characteristics: notch sensitivity and energy absorption.

Notch sensitivity results primarily from the concentration of the tensile stresses around sharp changes in section and is associated with the ease of propagation of cracks. In a notched prestressed member under tensile load, if there is a concentration of tensile stress, there will also necessarily be an equivalent concentration of compressive prestress; it will thus generally be possible to ensure a residual compressive stress at the root of the notch under working load. Rupture strength is not affected by notches in the compressed material. The danger of exaggerated local compressive stresses under minimum external load remains real, of course, but even failure under these stresses seldom leads to overall collapse and, being associated with minimum load, is soon revealed.

Energy absorption is a function of the area under the deflection diagram and the extent to which this is controllable has already been shown. In general, the energy absorption will be related to that of the tendons; the novel feature is that this characteristic is combined with a stiffness under working load which is that of the compressed material which may be very hard and brittle. The composite body, formed as it may be of two brittle materials, can thus be endowed with a sort of pseudo-ductility.

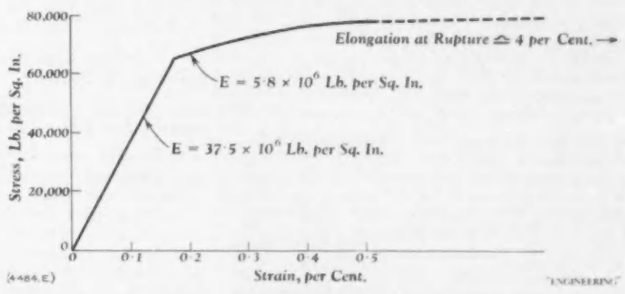


Fig. 5 Stress/strain characteristics of a rod of sintered alumina prestressed by high tensile steel wire.

It should be noted that prestress acts in this manner only in the direction of its own action. The material of a longitudinally prestressed beam will thus remain largely unaffected in a transverse direction, a state which the addition of a transverse prestress (either localised or general) will remedy.

A body prestressed in three mutually perpendicular directions is something of an elastic curiosity. The incompatibility between high degrees of hardness and of energy absorption is familiar: either a material is hard and cracks readily or it is ductile and readily deformable. The triply prestressed body resolves this incompatibility. It can be extremely hard with a high internal friction; the pseudo-ductility noted above will be manifest in three dimensions and cracks will not propagate themselves; the body will have a high energy-absorption capacity.

So far a material of negligible tensile strength has been considered. It is clear that a structure formed of such a material will be neither weaker nor stronger if formed of a series of segments whose joints lie roughly perpendicular to the principal stresses in the manner of the voussoirs of an arch. This ability to form a monolithic structure from small segments is of the greatest practical value, since shapes thus become possible which it would be either difficult or impossible to form in one piece. It will be noted that no more material, either tensioned or compressed, is needed in a segmental structure than in the same structure if formed in one piece.

PRESTRESSING AGAINST COMPRESSION AND SHEAR

It appears at first sight that prestressing, whilst reducing tensile stresses, can only do so at the expense of exaggerated compressive stresses. This is not necessarily true. Consider, for instance, a beam subject to bending in one direction only, as shown in Fig. 4. By applying an eccentric prestress acting at the edge of the kern (or " middle third ") tensile stresses are eliminated and there is no increase in compressive stresses. Furthermore, if a fraction of the bending moment is permanent, the eccentricity may be increased even farther to produce a tensile prestress which will reduce the compressive stress.

If, however, a section is subjected to equal positive and negative moments, then clearly the compressive stress is double what it would be without prestress. It will be seen that the total variation of bending moment is the critical figure for design, rather than the maximum absolute value. Under direct compression, prestressing has no value, unless it is possible to apply a biaxial prestress in a plane perpendicular to the load, e.g., by tensioned binding, when the compressive strength may be greatly increased.

In materials of low tensile strength, shear is dangerous because of the principal tensile stresses set up. The addition of a permanent compression in one direction clearly reduces these stresses; in two directions, prestress can eliminate them completely. It is possible in this way to ensure the safety of a structure under its design load.

It is much more difficult, however, to design for a given rupture load, for little is known about the failure of brittle bodies under compound states of stress. Promising theories exist, e.g. that expressing strength in terms of tensile strength and coefficient of internal friction, but they lack confirmation. In consequence, the design of sections in shear requires prudence in dimensioning, though it must be admitted that no dangerous inadequacies in present design methods have been revealed in the already extensive use of prestressed concrete.

MATERIALS

The materials to which this technique of prestressing applies, that is, those of high compressive and low tensile strength, are the commonest on earth, including those which either form the bulk of the earth's crust or can be

made from it with the least expenditure of energy.

They include ceramic bodies and all those materials in which hard inert particles are bonded together by hydraulically setting cements, by synthetic resins or by sintering. Many of these materials are well known in other branches of engineering but have escaped attention for structural uses on account of their low energy-absorption characteristics and their low tensile strength. Both in strength and in stiffness, the range is large and the upper limit is high; sintered alumina, for instance, with a density of about 3·6 is quoted as having a compressive strength of over 100 tons per sq. in. and a modulus of elasticity of over 40 × 10^6 lb. per sq. in.

The standard material for tendons is high tensile steel wire, with strengths which, in present-day commercial production, can reach 170 tons per sq. in. tensile strength.

The use of glass fibres was first bruited as long ago as 1943, but little progress has been made because of the very high strength needed to make such fibres competitive in cost with steel. This consideration relates to civil engineering construction, where the weight of the tendons is hardly ever a primary concern. The use of tendons of high specific strength may, however, show such advantages in lightweight structures that there would be a strong incentive to tackle the many problems which need solving before high-strength glass fibre tendons become practical.

It is of interest to examine the characteristics of a prestressed rod of sintered alumina which is stressed by high tensile steel. For alumina the compressive strength is assumed to be 130,000 lb. per sq. in., the tensile strength 10,000 lb. per sq. in., the modulus of elasticity 40 × 10^6 lb. per sq. in. and the specific gravity 3·6; steel to have a tensile strength of 380,000 lb. per sq. in., a modulus of 28 × 10^6 lb. per sq. in. and a specific gravity of 7·85. These figures are not unrealistic. Consider also that the alumina rod has a sectional area of 1 sq. in. stressed to 60,000 lb. per sq. in. by 0·261 sq. in. of steel stressed to 230,000 lb. per sq. in. This gives a composite body with the following estimated characteristics:

Cross-sectional area ..	1·261 sq. in.
Mean specific gravity ..	4·48
Mean modulus of elasticity	37·5 × 10^6 lb. per sq. in.
Mean modulus for loads greater than cracking load	5·8 × 10^6 lb. per sq. in.
Mean U.T.S.	78,600 lb. per sq. in.
Cracking stress	65,600 lb. per sq. in.
Compressive strength ..	65,600 lb. per sq. in.
Specific tensile strength ..	17,000 lb. per sq. in.
Specific stiffness	8·38 × 10^6.

The compressive strength given assumes elastic behaviour right up to rupture; plasticity would increase this figure and would also modify deductions from it of bending strength.

There is reason to suppose that the steel would support a large number of variations of stress of up to an amplitude of about 50,000 lb. per sq. in. The stress in the composite body corresponding to this steel stress would be 67,000 lb. per sq. in. A variation of load of more than this amplitude would be expected to produce fatigue failure no matter what the mean value. If the range included the cracking point, fatigue failure would occur earlier.

Fig. 5 shows the form of the stress/strain diagram based on these estimated figures, which inspire the following comments:

(*a*) The specific strength is reasonable; the specific stiffness is high.

(*b*) A monolithic structure could be built up from pre-formed elements; the shape efficiency would be high.

(*c*) It is relatively rare that there is not a predominance of bending moment in one sense; with such predominance there is a saving of steel and reduction of mean specific gravity.

(*d*) The material considered is highly refractory.

(*e*) The general aspects of security, relief of stress under excess load, fatigue strength, etc., are attractive.

(*f*) The use of glass fibres instead of steel would reduce the mean density very considerably.

BEHAVIOUR AT HIGH TEMPERATURES

Many highly refractory materials are strong in compression; none are strong in tension at high temperatures. On the other hand, metals have a small but appreciable tensile strength at temperatures of a moderately high order though they are in general of little value as tendons at really high temperatures. They could, however, be of value as secondary reinforcement. The interest of prestressed structures submitted to high temperatures lies in the capacity to separate the tendons from the body of the structure, to insulate them from the source of heat and even to cool them.*

CONSTRUCTION

The problems met in designing and constructing a prestressed member are neither more simple nor more difficult than for a classic structure; they are just quite different. They are broadly twofold:

(*a*) The problem of forming a basic compressive structure capable of supporting the full range of stresses and prestresses involved. The factors in this problem are the following:—

(i) Most of the materials in question are castable, but do not flow well and many need pressure and vibration to develop the compaction needed for strength.

(ii) Those which are fired have large residual strains.

(iii) Some nevertheless exist which can set hydraulically with very small setting strains and then be fired with correspondingly small residual strains.

(iv) The problem is greatly eased by the ability to subdivide the structure into small elements assembled later by prestress.

(*b*) The problem of arranging the tendons in such a way that the desired state of stress is produced. This, of course, is basic, and is a problem which the designer should have in mind from the outset; it will condition every decision made, whether referring to material, shape, disposition or stress. The importance of this aspect is expressed in the saying that the main problems of prestressing are the practical ones of ensuring that the calculated prestress is applied with precision, security and economy.

The techniques available are three in number as follows:

Pre-tensioning.—The tendons are stretched and anchored on the mould and the material is cast around them and allowed to set. The tendons are then released and transfer load to the structure by bond. This method is cumbersome and somewhat inflexible; it is difficult, for instance, to have curved tendons or to have tendons in two directions. Segmental construction is not possible, nor is cooling of the tendons.

Post-tensioning.—The structure is first either cast in one piece or built up from segments; the tendons are then laid in grooves or fed down holes or voids, tensioned and anchored. The problem here is one of anchorage; many solutions exist and many more will doubtless be developed.

Winding.—Wires, strips or tapes are wound under tension around the periphery of a body; anchorage is helped by a few slack turns. This is a useful auxiliary to the other methods; it is particularly useful for pressure vessels.

CONCLUSIONS

The technique of prestressing can combine readily available materials to form a composite medium, the elastic characteristics of which are controllable and highly attractive.

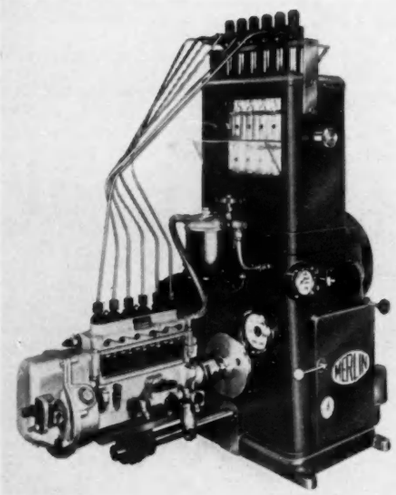
The employment of this technique has spread during the last 25 years over the whole range of civil engineering, from flooring joists to harbour works, from railway sleepers to dams, despite the fact that prestressing is a high-performance technique and civil engineering is more interested in economy than in high performance. In applications where performance is critical, prestressing has much to offer.

* Certain applications of this principle are covered by patent.

INJECTION PUMP TESTER

Following the introduction by the Merlin Engineering Company, Limited, Hebble Mills, Halifax, of their fuel-pump test bench, the company have now produced a bench-mounting model for the smaller factory or garage. One of the new machines is shown in the illustration.

The pump to be tested is mounted on a projecting arm by means of one of a number of types of mounting plate, which are designed for receiving types A, AA or B injection pumps. Full tests can be carried out on the pump, to enable complete servicing to be done. A variable-speed unit can be included, mainly for regulating governors. The basic model has a three-speed pulley for standard pump testing.



A fuel-oil injection-pump tester for the smaller garage is now available. It will accommodate most types of pump.

It is claimed for the machine that high-pressure phasing and timing to within a two-minute phase angle can be carried out, using the calibrated dial on the pump drive shaft. The three fixed speeds are 200, 600 and 1,000 r.p.m., while the variable speed control offers a range of from 175 to 1,200 r.p.m. The standard machine is powered by a 1½ h.p. three-phase motor.

A trip mechanism on the shaft stops the operation after exactly 100 injections have been made by the pump, so that the quantity of oil passed by each plunger can be measured in the six receiving tubes. Multiples of 100 injections can be obtained if desired.

Any pump which has elements not exceeding 10 mm. stroke by 7½ mm. diameter can be accommodated, and provision is also made for the distributor types of pump now on the market.

★ ★ ★

In our article describing the operation and maintenance of Diesel locomotives at the Port Talbot steelworks (June 28, page 825) reference was made to some mobile lifting jacks. We have since been informed that these were manufactured by the Whiting Corporation of Harvey, Illinois, U.S.A., and supplied by the Incandescent Heat Company, Limited, Cornwall-road, Smethwick, Birmingham, and are actually electrically operated with capacities of 25 tons.

DATA ON HUMAN PERFORMANCE FOR ENGINEERING DESIGNERS

Continued from page 199

By K. F. H. Murrell, M.A., F.R.P.S.

In its widest sense a display is any means of conveying information to an operator about the state of his equipment. He may get this information visually, by seeing part of the machine move or by means of a remote display such as a dial; aurally by listening to his machine and through warning devices such as bells; tactually, by the shape of his controls or their position.

All have this in common: they must convey information to the operator unambiguously and, usually, quickly.

Visual Displays

In this section the design of dials and indicators will be dealt with.

Definitions.—There is ambiguity in much of the writing on the subject of dials and indicators because of differences in the meanings given to the various expressions used. Therefore, to avoid ambiguity the following definitions are given:

Term	*Definition*
Visual display	A means of providing visual information about the state of a system, which cannot be obtained directly by the senses; e.g., a gauge showing the amount of liquid in a container when the shape of the container prevents the surface of the liquid being seen.
Dial	A numbered scale, curved or straight, on which the information is given by a pointer; e.g., a steam pressure gauge.
Indicator	A display which gives non-quantitative information on the state of a system; e.g., a display showing whether a valve is open or shut.
Counter	A display which gives values directly in numerals.
Scale space	The physical size of the interval between two scale marks.
Scale interval	The number of units in a scale space.
Called space	The physical width of the unit into which the scale space has to be sub-divided by eye.
Called number	The number of units in the called space.
Number system	The units in which the main graduations are marked.

(For a diagrammatic presentation of some of these terms see Fig. 18.)

Uses of Visual Displays.—The uses of visual displays may be divided into four groups, according to whether they are used with or without controls. The information required is, in each instance, rather different, and the design of the display will depend on the use to which it is to be put.

Dials and counters may be used with controls:

(*a*) For setting	Using a control to bring a pointer to a given value; e.g., setting a generator to a given voltage.
(*b*) For check controlling	Restoring a pointer to a given value whenever a deviation from this value is observed; e.g., adjusting pump speed in order to maintain pump discharge pressures.
(*c*) For tracking	Continuously following a changing pointer with another pointer.

Dials and counters may be used without controls:

(*d*) For check reading	Noticing a deviation from normal and taking executive action; e.g., the displays in a control room where, when a change from normal reading occurs, instructions are given to somebody elsewhere to do something about it.
(*e*) For qualitative reading	Understanding the meaning of a change in value. This is very closely related to check reading but differs from it in that no "normal" reading is involved; for instance, a dial displaying bearing can give information both on the direction of the change and on the rate of change.
(*f*) For quantitative reading	Reading a value and reporting or recording it.
(*g*) For comparison	Comparing one indication with another.

Indicators may be used with controls:

(*h*) For indicating	Showing the state of a mechanism when under human control.

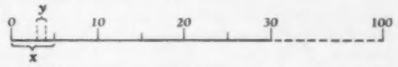
Indicators may be used without controls:

(*i*) For warning	Showing the state of a mechanism when under auto-control. An example of the difference between warning and indicating is the wall panel fitted for electric cookers or refrigerators; a shutter shows whether the switch is on or off (indicating), and a red light shows whether current is actually passing (warning).

These various uses must clearly overlap from time to time; for instance, an instrument used for check-reading may also be used for qualitative reading, as when a steam-pressure gauge gives information on the rate of increase of pressure when starting up (qualitative), but when running shows whether the pressure is maintained at its correct value (check). The requirements for the best type of display for these different purposes may therefore also conflict, and it is therefore often necessary to find a compromise.

It is important to choose the right kind of display for the use to which it is to be put. For instance, the roadman operating a pneumatic drill does not really care whether his compressor works at 50, 100 or 150 lb. per sq. in. All he needs to know is whether the pressure is above a minimum or below a maximum. These points can be clearly marked by a green band on a pressure gauge with a higher red band above the maximum and no other indication is necessary. In so doing the operator is relieved of the need to remember values and the equipment is made easier and safer to operate.

Decide exactly what information is required by the operator and choose and design the displays to give just that information in the simplest way possible.



200 Lb. Gauge Read to the Nearest 2 Lb.

Scale Space = x in Inches etc.

Scale Interval = 10 Units

Called Space = y in Inches etc.

Called Number = 2 Units

(4356.R.) "ENGINEERING"

Fig. 18 The diagram illustrates the definitions of the terms used in the design of visual displays.

Choice of Displays

A great deal of research has been carried out on the best form of display for the different uses given above—much of it with contradictory results. The recommendations given below are derived from an assessment of the results of this research and are to that extent tentative.

For Setting.—Horizontal linear dials are set slightly more quickly and accurately than circular or vertical linear when used singly. This is probably because the relationship between the pointer and the control is less ambiguous. Scaled instruments probably give quicker settings than do counters. It may be concluded, therefore, that for single instruments, preference should be given to horizontal linear with the control below the centre of the scale, but this arrangement will probably not be satisfactory when mounted in multiple panels, and circular or vertical linear may be used with the control beneath them, according to circumstances.

For Check Controlling.—The requirements of controlling appear to be similar to those for setting. The relationship between the scale and the control being similar for both uses.

For Check-Reading Single Instruments.—Moving-pointer instruments are superior to moving-scale instruments, when the check-reading of single instruments is required. Circular dials are better than vertical linear dials. This presumably is because more of the pointer is visible. When multiple dials are used in panels for check-reading the same general principle that moving-pointer instruments are better than moving-scale instruments applies. Vertical linear dials may be used instead of circular dials with some saving of space and probable increase of speed of noticing deviations from normal when a panel is watched for a long period.

For Qualitative Reading.—(*a*) Direction of change. Vertical linear dials are probably better than circular dials because an upward movement of a pointer will always indicate an increase in value whereas on a circular dial when the pointer is in the right-hand segment a downward movement of the pointer indicates an increase in value. This effect may perhaps be overrated, because Morley and Suffield in their experiment on check-reading have shown that there was no greater difficulty in determining the meaning of a deviation from 3 o'clock than there was from 9 o'clock provided that no control movement was involved. (*b*) Rate of change. It seems likely that a circular dial is best because the angle of the pointer will convey information rapidly. It would seem also that counters are unsatisfactory for this purpose.

For Quantitative Reading.—Direct-reading counters are much superior to any other type of display for quantitative reading and should be used wherever possible, in preference to dials, when a quantitative value is the only information which the display is required to give. In general it may be said that the design of the actual scale of a dial (which will be dealt with later) is likely to have far greater influence on the accuracy and speed of reading than will its shape.

For Comparison.—Circular dials have been shown to be faster but rather less accurate than counters and that it is impossible to make accurate judgments on an unscaled dial within 10 deg. When extreme accuracy of comparison of values is required counters should be used.

For Indicating.—Pointers, shutters or lights are usually used. No work on these has been traced.

For Warning.—Shutters, lights and auditory devices can be used.

The Readability of Dial Faces

Recommendations on the method of marking dial faces are being drawn up by the British Standards Institution and are expected to be published during 1957. The suggestions given below, while they are derived from the same experimental material as those of the B.S.I., are based on reports published by the author before the B.S.I. started its deliberations. It is recommended that this section should be used in conjunction with the B.S.I. recommendations.

The readability of dials depends on the dial size, reading distance, scale spacing, the number of units in the scale spacing, and the accuracy to which the dial has to be read and these are all inter-related. The number system, pointer length, face markings and bezel design also may have an independent influence on the readability.

Setting Out a Scale.—The basic principles influencing the setting out of a scale of any given range are:

(*a*) The smaller the number of scale marks (within the limits laid down below) the quicker and the more accurately will the scale be read. It can also be read at a greater distance. Thus a 100 unit scale subdivided into 100 parts is actually read less accurately than one subdivided into 20 parts.

(*b*) Choose sufficient scale marks so that the space between them will be interpolated into fifths by eye.

(*c*) Never allow for a reading accuracy (by interpolation) greater than the mechanical accuracy of the instrument. This means that normally an industrial scale (i.e., with an accuracy of 1 per cent. or less) should be divided into 20 or less parts.

(*d*) Number the major scale marks in 1's, 2's or 5's (and decimal multiples or submultiples). Never use 4's or 8's or decimals

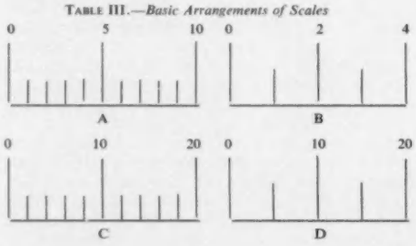
such as 2·5. Use the lowest number system possible without overcrowding. The minimum space between groups of digits should be equal to the height of a numeral.

(*e*) There should be a minimum number (never more than four) of minor scale marks between the major marks.

As an example of the application of these principles a 200 lb. gauge to be read to the nearest 2 lb. is shown in Fig. 19. We must discard (*c*) and (*d*) because they both have unsatisfactory number systems and they require more sub-divisions than the other scales. We must discard (*a*) because the numerals will be too close together. Of the two remaining we select (*b*) because it has a lower number system than (*e*) and less sub-divisions are required. Now (*b*) can be sub-divided into two's, five's and ten's (Fig. 20.) Two's are out because there will be ten sub-divisions between the numbered intervals and we select the ten's in preference to the five's because there are fewer sub-divisions (and therefore less chance of mistaking the sub-division being interpolated) and interpolation is into fifths. Our final scale therefore is numbered in twenties and subdivided into ten's.

Not all scale maxima will permit these principles to be applied as easily as this and therefore some compromise is necessary. Table III gives four basic arrangements from which most scales can be derived.

TABLE III.—*Basic Arrangements of Scales*



Scale maximum	Type	Can be read to nearest	Remarks
15 units	A	0·2 unit	15 units only, not multiples by 10.
12-20 ,,	B	0·2 ,,	Maxima must be multiples of 2
30-50 ,,	C	0·4 ,,	,, ,, ,, 10
60-100 ,,	D	1 ,,	,, ,, ,, 10

The above table applies to scales with maxima in the range 12-100 units.
For scales with maxima in range 1·2- 10 units divide by 10
,, ,, ,, ,, ,, 120- 1,000 ,, multiply by 10
,, ,, ,, ,, ,, 1,200-10,000 ,, ,, ,, 100
and so on.

Examples of use:

Scale maximum required about 35—use C with max. 40
,, ,, ,, ,, 150—use B×10 with max.160
,, ,, ,, ,, 5,500—use D×100 with max. 6,000
,, ,, ,, ,, 10—use D÷10 with max. 10

Reading Distance.—The relationship between size and reading distance is based on the minimum angle subtended at the eye by the interval between two scale marks which for any given distance is constant. Therefore, the reading distance for a particular scale length will depend upon the number of parts into which the scale is divided.

In practice, however, it is desirable to have reading distances associated with a particular nominal size and these are, for typical sizes, given together with the minimum scale spacing in Table IV.

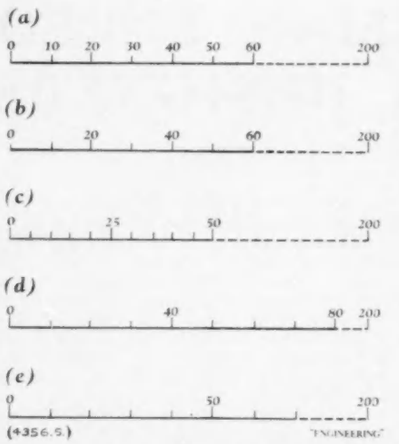


Fig. 19 The various ways in which a 200 lb. gauge might be calibrated. Scale b is to be preferred.

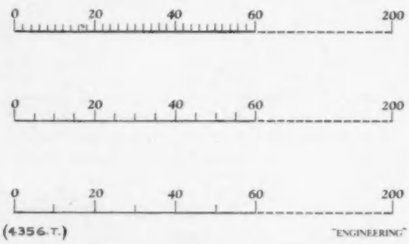


Fig. 20 Scale b having been selected, it is necessary to insert further sub-divisions.

The Design of Scale Marks.—The length of the major numbered scale marks should be between half and one times the scale spacing and the length of the minor marks should be half that of the major marks. The thickness of the major marks should be 5 to 10 per cent. of the scale spacing or equal to the thickness of the numerals (this will usually amount to much the same thing) and the minor marks should be two-thirds the thickness of the major mark. The divisions may be joined by a radial line but it is recommended that there should not be a second line to form " tramlines."

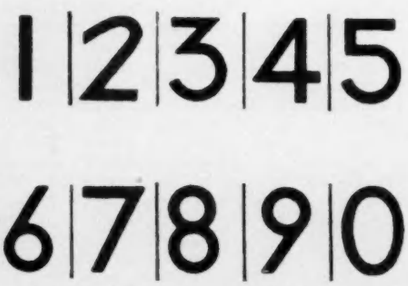


Fig. 21 A set of numerals specifically designed to avoid confusion.

TABLE IV.—*Sizes of Scale Markings*

Nominal size of gauge, in.	Circular			Eccentric			Edgewise		
	Diam. of 270 deg. scale, in.	Max. reading distance, ft.	Min. scale spacing, in.	Scale length, in.	Max. reading distance, ft.	Min. scale spacing, in.	Scale length, in.	Max. reading distance, ft.	Min. scale spacing, in.
2	1·7	5	0·20	1·7	1·5	0·06			
2½	2·1	6	0·25	2·1	2	0·08			
3	2·5	8	0·30	2·6	2·5	0·10			
4	3·3	10	0·40	3·4	3·5	0·14			
6	5·0	16	0·60	5·1	5	0·20	4·5	4·5	0·18
8	6·7	20	0·80	6·9	7	0·26	6	6	0·25
10	8·3	26	1·00	8·6	8	0·30			
12	10·0	32	1·20	10·3	10	0·40			

There should be a clear break whenever possible between the ends of the scale. Christensen[29], for instance, found that there were 43 per cent. reversal errors around the zero when the scale was continuous and he recommended a " staircase scale " in which the small graduations increase in size with increasing value to get over this difficulty when a continuous scale must be used. For most purposes the scale should increase clockwise.

Position of Zero.—Several workers have investigated the effect of different positions of zero on accuracy of scale-reading, and in general they seem to agree that it is not of any enormous importance where the zero is placed. There is, however, a slight preference for the 12 o'clock position because most people are influenced by the habit of reading clocks with zero in that position. It would seem that the present arrangement of scales on pressure gauges of starting with zero half way between 7 and 8 o'clock has grown up through the custom of fitting boilers with gauges whose pointers would point vertically upwards when reading the maximum, but allowing for 100 per cent. above maximum for test for insurance purposes. As is explained elsewhere, there are some very good reasons why zero should not be retained in this conventional position and a change can be made with confidence because several workers have found that the ease of reading from a scale is little affected by the portion of the scale which is being read.

The Design of Numerals.—For black on white the ratio of height/stroke thickness should be 6 : 1 and for white on black 10 : 1. Transilluminated letters should be in general even thinner, about 40 : 1. No advantage is to be gained in legibility in making the figures tall and thin, the greatest legibility being when the height/width ratio is between 3: 2 and 1 : 1. The space between digits should be approximately half the width of the digit.

The design of the digits has a very marked effect on their legibility and the descending order of legibility appears to be 1, 7, 0, 4, 3, 2, 9, 6, 5 and 8. The factors influencing the design of these numerals have been investigated closely by Berger[18] who arrived at the following results:

(*a*) The angle at the base of 2, in 7 and of the tails on the 9 and 6 should be 45 deg.

(*b*) The top of 4 should be closed.

(*c*) The bar on 5 should go across the full width.

(*d*) The bar on 3 should go half way across the full width.

The thickness of the numerals should be uniform, thick and thin strokes should not be used. In selecting a set of numerals particular attention should be given to those which are likely to be confused. Fig. 21 shows a set of numerals designed by Mackworth[21] and illustrates the type of numeral designed specifically to avoid confusion.

Pointers.—The pointer for a circular dial should have a long even taper with the tip about the same thickness as the minor scale marks. The length should be such that the tip just touches them. The whole of the pointer should be visible from the collet to the tip but it should not extend beyond the collet. If some form of counterbalance is required it should be painted the same colour as the dial face. Care should be taken that the pointer is not so thick that it obscures the numerals.

Pointers for straight scales require to obtain maximum attention-getting value in very short length. Therefore they should be fairly fat at the end away from the scale thinning down, probably with a convex taper, to a fine thin point. Here again care should be taken to avoid obscuring the numerals.

Colour.—The best results are obtained when there is maximum contrast between the numerals and the dial face. In general the use of black figures on white is to be recommended except when dark adaptation is required. The principal reason for making this choice is that when dials are mounted on panels the reflection factor of the panel should be about half way between

that of the dial face and the general surroundings. The dial face should never be darker than the panel. From this it follows that unless an all-black panel is to be used—and this should never be used except when dark adaptation has to be maintained—a white-faced dial must be used.

The bezel surrounding the dial should be just sufficient to separate the dial from the panel. It should not be black and heavy, otherwise it distracts the eye from the pointer. This is particularly true of linear gauges. (See Fig. 2.) For the same reason the bezels should not be highly polished. Self-coloured anodised aluminium or sandblasted brass are both satisfactory bezel materials. If coding is required the bezels can be coloured either to indicate to which control a gauge belongs or in accordance with a known code such as that used on pipes. The use of a code might dispense with labelling.

Long-Scale Instruments.—Grether[19] examined a number of long-scale instruments in which two pointers were used and compared them with direct-reading counters and combinations of counters and pointers. He showed that the direct-reading counter was very superior to two-pointer instruments, with the counter for coarse reading and pointer for fine reading next best, and a vertical linear moving scale a third best. All these types have under 1·5 per cent. errors. Other workers have shown that instruments using two scales, one coarse and one fine, lead to an unnecessarily high number of errors, usually of 100 or 1,000, according to the design of the particular instrument. From this it follows that in this type of instrument the value of the thousands or hundreds, as the case may be, should not be given by means of a supplementary pointer but should be presented clearly and unambiguously by a counter, or failing that a moving scale.

Indicators

Pointers or shutters are most commonly used for indicating and shutters and lights for warning. Only the latter seem to have been the subject or research.

If a pointer is used its direction of movement should follow that of its control (see section on control-display relationships). Although shutters are extensively used, as for instance in telephone exchanges, their attention-getting value seems to be low unless they are accompanied by a noise, as in a domestic bell system.

When used for warning, flashing lights appear to be better than steady lights, and the brighter the light the greater is the superiority of the flashing light. The difficulty, however, with this form of warning is that for complete safety it is desirable that the light should remain on when all is well. A compromise might be for a light to change from steady to flashing when a warning has to be given, but no work on this or on any other form of warning other than auditory warning has been traced.

The colours to be used in a six-colour signalling system have been examined by McNicholas who concluded that red, orange-yellow, white, green, blue and purple were better than a set containing orange and yellow and omitting purple, provided that the blue and purple were 15 to 20 times as bright as the white. The chromaticity tolerances of these colours may be found in Stiles *et al.* who review the work on light signals.[22]

Holmes, working in darkness, concluded that blue and purple are not satisfactory signal colours unless the blue is very saturated to avoid confusion with green and white. Red is good and if used without orange its wavelength should not be greater than 610 mμ. Yellow, wavelength 590 to 596 mμ, can be confused with white if it is not saturated. When no white is present wavelength down to 583 mμ may be used. It may be concluded that four or five-colour systems can be used with confidence. A six-colour system may also be used provided that the colours are carefully selected. This applies when a light is seen alone; work on combinations of lights has not been traced.

Lights which are incorporated in panels and which are normally "on" should have a brightness about three times that of the panel background and never more than 5 : 1, otherwise they may cause glare discomfort to the operator.

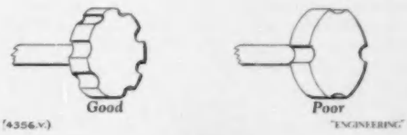


Fig. 22 Serrations on knobs should be evenly spaced and not widely separated.

Fig. 23 The various bar-type knobs should be confined to switching operations with detents.

Auditory Displays

Auditory displays are almost invariably used for warning purposes. To be effective they should be at least 10 dB above the background noise. Where more than one auditory warning is employed they should be of different pitch (if they are of the same kind) or of different kinds so that they are clearly distinguishable. Intermittent sound is better than a continuous sound and Houston and Walter[20] recommend that a pure tone of about 2,500 c.p.s. should be used. Bells are in general found to be better than horns and it is suggested that this is because they produce an intermittent sound.

Information may also be conveyed by "clicks" as when a control is turned to a predetermined position or when used as a code in signalling. In either case it is important that the sound should be heard clearly.

Tactual Displays

The distinguishing of controls is the most common use of tactual displays. This may be achieved by position, size or shape.

For knobs on lever type controls about eight basic shapes can be distinguished (see ref. 12, page 130). Knobs can be coded by knurling when they are less than ¾ in. deep or with serrations when they are more than ¾ in. deep, which should be evenly spaced and not widely separated (Fig. 22). Bar type knobs can also be used (Fig. 23) but they should be confined to switching operations with detents.

(*To be continued*)

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GOLDINGTON POWER STATION

The conception of Goldington power station dates back to the end of the war, when Bedford Corporation sought for a site. The B.E.A. took over the scheme and construction began in 1951, after the capacity had been increased to 180 MW. The first of the 30 MW sets was commissioned in 1955 and it is expected to commission the last of the six in January, 1958. The station was officially opened on August 16 by Major S. Whitbread, the Lord Lieutenant of the County.

All six generating sets are of British Thomson-Houston make, but all are not of the same design. The first two have the steam valve gear mounted above the turbine while the last four are the modified form in which the gear is mounted below. Also the high-pressure cylinder is reversed so that the steam inlet is adjacent to the low-pressure cylinder. It is claimed that this improved design limits the momentary rise in speed when the load is removed to 5½ per cent. Magnestat regulation is used on all machines but the one yet to be installed is to have an alternating current version as a trial.

Steam for each set is supplied from a Clark Chapman boiler with an evaporative capacity of 30,000 lb. per hour, maximum continuous rating, fired by pulverised fuel. Steam conditions at the stop valve are 625 lb. per sq. in. at 865 deg. F. This station was one of the first to install the Permutit mixed-bed system of water treatment and so also has an evaporator plant installed, though the latter is not often used and plant has not been ordered for the later sets. Enough cooling water for one set can be obtained from the river but for the remainder, cooling towers have been installed. All fuel is supplied by rail.

There are one or two unusual features incorporated in the plant; the first, the early installation of the mixed bed water treatment has already been mentioned, as also has the a.c. version of the Magnestat. The third is that the controls for the sets are grouped in pairs in air-conditioned rooms on the turbine operating floor between the sets and the boiler room; all sets are capable of completely automatic operation. Another is the automatic equipment for lighting the main burners using oil. In addition to lighting up, this apparatus also monitors the flame and at any sign of instability brings the oil burners back into operation. A fifth item is connected with the bucket elevators which lift the coal from the incoming conveyors to the boiler house bunkers. To conform to the requirements of appearance this has been made a vertical lift instead of the more usual inclined conveyor, and consists of a standard bucket and chain arrangement, but the bearings in the chain are made of nylon and are never lubricated. In the two years that the plant has been operating the wear has been completely negligible, being little more than a polishing of the surface. Other points are the fluorescent lighting system; the extensive use of single-core mineral insulated cable for wiring and the efforts to preserve the amenities by using coloured concrete for both the cooling towers and the chimneys, to blend with the rustic brick of the main structure.

Although the station is run on two shifts only, being shut down each night, an average boiler efficiency of 85 per cent. has been obtained and a station efficiency of 25·6 per cent.

★ ★ ★

TREATED WATER

A portable water treatment plant, operating on the Deminrolit principle, has been introduced by the Permutit Company, Limited, Permutit House Gunnersbury-avenue, London, W.4. The two sealed treatment cylinders are each 2½ in. in diameter and 20 in. long internally, giving a plant output of 6 gal. of pure water per hour. To determine the point when regeneration is required, a conductivity meter is incorporated in the base, which is suitable for use on single-phase alternating current. Also in the base are the control valves for running the unit. The maximum operating pressure should not exceed 50 lb. per sq. in.

Fig. 1 Fireflash is in service in a Royal Air Force squadron of Swift 7 aircraft.

Fig. 2 A Fireflash missile—seen here coated with ice—on test in the large cold chamber.

FIREFLASH

After successfully completing rigorous acceptance trials earlier this year, Britain's first air-to-air guided-weapon system "Fireflash" is now entering service with the Royal Air Force in a squadron of Swift 7 aircraft, where pilots are trained in the use of guided weapons. Although no information on the performance of Fireflash has yet been disclosed officially, the security door has been opened wide enough to take a look at some of the main constructional features and to learn from its designers and constructors, the Fairey Aviation Company, Limited, Heston, Middlesex, something of their philosophy of guided-weapon engineering.

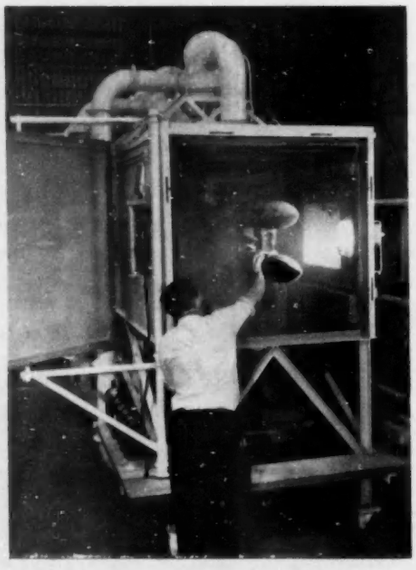


Fig. 3 An engineer, wearing a protective mask, checks the boost ignition and separation circuits of a Fireflash missile after it has been exposed to a simulated dust and sand storm for an hour.

THE PHILOSOPHY

It will be observed that we referred above to Fireflash, not as a guided missile, but as a guided-weapon system—that is, it is a closely-integrated concept which has been designed from the start not only for reliability and lethality in operation, but also for the minimum of servicing and pre-flight testing; the weapon system comprisies not merely the missile and the associated guidance radar in the parent aircraft, but also equipment for pre-testing and for assembling and installing the weapon on the aircraft prior to operation.

The fact that a guided weapon carries no human pilot adds heavily to the task of its successful engineering. Designers who have turned their attention to pilotless craft are, in fact, increasingly appreciative of the responsiveness and adaptability of the human pilot, who can often adjust his controlling actions to counteract a multiplicity of errors in the machine. In the guided weapon, on the contrary, if any single small thing goes wrong, the operation is doomed to failure. The system has, then, to be engineered for 100 per cent. reliability—and that involves some hundreds of flight trials using expendable missiles so that, in fact, a production line is in effect almost a necessity from the start—but it must be a flexible production line to allow for the many modifications that are inevitable as flight trials bring to light new deficiencies.

Thus the philosophy adopted by Fairey has been to design for production and for operational use from the inception of the project. The weapon may well pass through a number of prototype phases, but at each phase the current prototype is a missile which, in the current state of knowledge, could be an operational weapon. The trials philosophy follows the design philosophy. Each aspect of the weapon system is thoroughly tested in its environment in the laboratory before trials begin. Trials to prove and to develop the system components follow, by firings of prototype missiles degraded to include only the system components under test. As trials proceed, the fired missile approaches more closely the fully integrated prototype.

Reliability can only be achieved in the design stage by adequate recognition of its importance. A "reliability group" operates at Heston as a design advisory service, feeding back information to the design team from data collected and collated during manufacture, laboratory testing and trials. During its operational life, a component may be subjected to stresses arising from steady accelerations, shock and vibrations experienced during transport and its active missile life, from

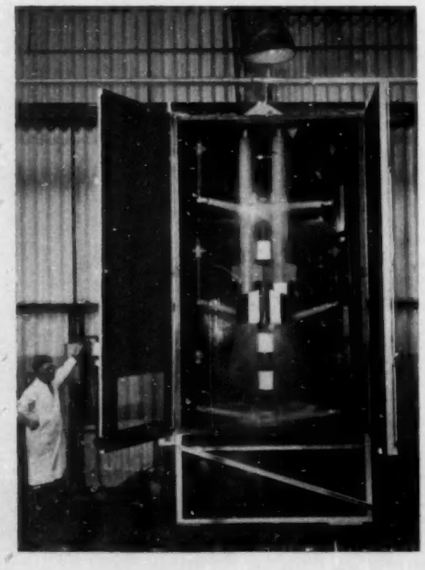


Fig. 4 (left) Fireflash subjected to driving rain simulated by twelve shower-heads. In this instance, the adjustable jets are being directed at exposed electrical components which are being tested for insulation resistance.

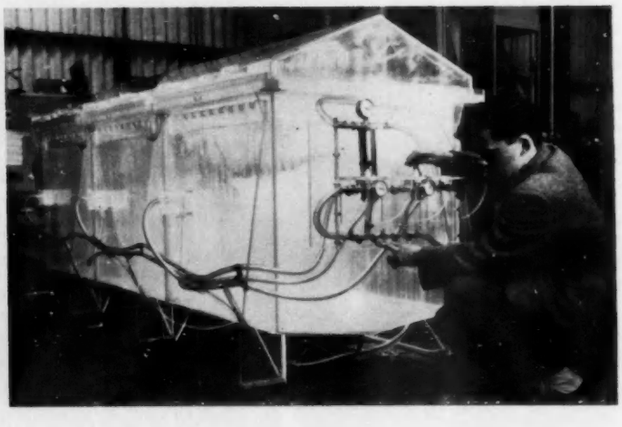


Fig. 5 (right) In the Perspex spray chamber, components can be tested under fine mist conditions, and in acid, alkaline and salt-laden atmospheres.

adverse climatic and atmospheric conditions—temperature, pressure, humidity, dust, contamination, etc.—from storage, and just age. A comprehensive programme of environmental type testing for specimens of each component is, therefore, drawn up, and during the development phase of each component a specimen is subjected to a shortened version of this test programme in order that the reliability of the component shall be adequate for trials use, and that it shall have a reasonable chance of meeting the type-approval requirements later.

ENVIRONMENTAL TEST FACILITIES

In support of this philosophy a comprehensive environmental test laboratory has been built up at Heston. Two 8 cub. ft. capacity stratospheric chambers are available covering the temperature range —75 deg. to +85 deg. C., humidity up to 100 per cent. at 85 deg. C., pressures down to the operational altitudes. Three further 6 cub. ft. unpressurised chambers can be used in the temperature range —50 deg. to +85 deg. C. A large chamber (Fig. 2), 18 ft. by 5 ft. 6 in. by 4 ft. 6 in., be operated over the temperature range — 50 deg. to + 86 deg. C., again with full humidity control. Tropical-life cycling chambers and mycological chambers for fungus and bacterial growth, up to 9 ft. by 4 ft. by 4 ft. size, a sand and dust chamber (Fig. 3), and a driving-rain cabinet, equivalent to 100 in. of rain in an hour (Fig. 4), each able to take a complete fully-functioning missile are available. Other climatic facilities include ultra-violet radiation equipment, water, acid, alkaline and salt-spray booths (Fig. 5), to prove the corrosion resistance of components and complete missiles. Vibration equipment includes a 5 kW moving-coil exciter, many 1 kW exciters, scanning and control equipment, calibrators and vibration transducers of various patterns. Bump machines, impact testers, centrifuges, etc., are available in various capacities. These facilities supplement adequate structural-test and pneumatic and hydraulic-test equipment.

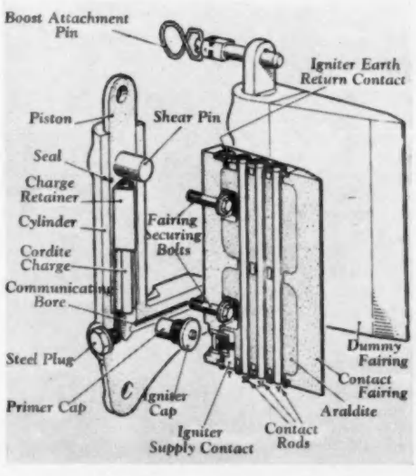


Fig. 6 (left) Cut-away view of boost separation unit.

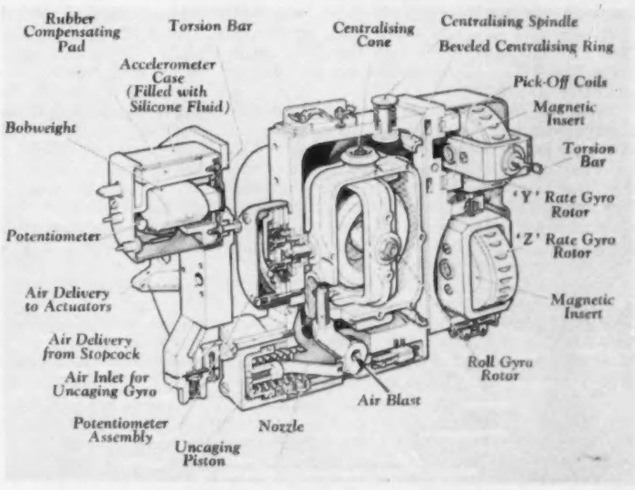


Fig. 7 (right) Cut-away view of control-instrument sub-assembly comprising two rate gyros, one roll displacement gyro and a lateral accelerometer. (One lateral accelerometer has been deleted for clarity.)

THE HARDWARE

Turning now to the weapon system itself: in general, in a guided weapon, accurate delivery of the "payload" is normally achieved by a closed-loop guidance system. Apparatus, either within the missile or outside it, detects whether the missile is accurately on course to the target, measures the error between the actual course of the missile and the required course, and informs the missile of this error. The guidance system is thus the "intelligence" of the missile, and it gives commands to the control system to reduce the error between the actual course and the required course. The control equipment, in carrying out the commands of the guidance system, operates upon the airframe, again monitored by sensing instruments such as accelerometers and gyroscopes, in feed-back loops, to achieve the desired flight programme by virtue of the aerodynamic properties of the missile. The internal loops must be so designed that the required manoeuvres can be carried out accurately and stably, with minimum control lags and overshoots.

The Fireflash weapon system comprises a fighter aircraft fitted with a radar beam, a gun-sight, a simple permission-to-fire computer, and a number of missiles, with various aircraft-to-missile services. Essential ground ancillaries are Fireflash's "OATS" (operational airfield test set) on which all the electrical circuits and mechanical components can be given a rapid and comprehensive pre-flight check before the warhead is fitted; an assembly and handling trolley; and the packaging drum which has been developed to protect the equipment from shocks during ground transportation.

The missile consists of a central unmotored cruciform-winged dart, about 7 ft. 6 in. long and 5½ in. in diameter, which is boosted to maximum speed, around Mach 2, by two solid-fuel rocket motors attached externally to its forward end. During the boost phase the unguided missile is spun by offset venturis to minimise dispersion due to asymmetric thrust. When the motors are all-burnt, an explosive separation device throws off the spent motor cases laterally, leaving the dart to coast towards the target. The rudders, indexed at 45 deg. to the wings, unlock at separation and the missile roll-stabilises by aileron-wise rudder deflections to a datum established at launch. As soon as the roll error is reduced to within specified limits, guidance commands are switched to the control blocks. The missile position relative to the axis of the radar beam, measured in polar co-ordinates, is interpreted as Cartesian linear errors resolved in the two control planes. A pneumatic actuator, operated by electro-pneumatic relay valves, applies rudder deflections tending to reduce the linear errors and to return the missile towards the beam-axis. During this "gathering" phase, the maximum lateral acceleration is limited by clamping diodes. The missile then rides along the beam axis, following any beam motion which may occur.

The accuracy of the weapon then depends upon the accuracy with which the beam is laid on to the target. In the daylight fair-weather rôle, the pilot of the firing aircraft tracks the target by keeping the target image at the centre of his gun-sight graticule. The radar beam axis is accurately harmonised relative to the gun-sight axis, so that the only significant guidance error introduced is that due to the aim-wander of the pilot-aircraft combination in tracking the target, which may be evading.

The weapon breaks down conveniently into the rear cylindrical portion of the dart, fitted with wings and rudders, which contains all the control, guidance and power supply equipment; and an explosive assembly comprising the two motors, their separation gear, the warhead and its fuse. This assembly can be offered up to the rear dart, which will have been fully tested on an operational airfield test set (OATS).

Structurally, the rear body consists of a magnesium-zirconium alloy extruded-and-forged tube into which a two-rail chassis carrying the internal equipment slides. The body rails are hollow extrusions forming air ducts for conveying air supplies from the parent aircraft for driving gyros, and also for warming up the components, during the pre-launch period. The wings and rudders are aluminium-alloy forgings machined only over their bosses. The motors are attached to each other by a U-shaped separation unit, and fittings on the motors mate with holes in the warhead case. The fuse attaches to the warhead, and a spacer device forward of the fuse tip pre-tensions the assembly to make it adequately rigid.

The separation gear comprises a twin piston-cylinder breech block containing 0·06 lb. of cordite. The pistons, attached to one motor, are held by shear pins in the cylinders attached to the other motor. A single igniter in the base of the unit flashes to the two separate charges in the two cylinders. A pressure switch, which arms on build-up of pressure in the rocket tube and fires when the pressure subsequently falls to 250 lb. per sq. in., is located in the nose of each motor rocket. These are series-connected so that, when both motors are all-burnt, a firing pulse is passed to the igniter. The pressure in the cylinders builds up until the shear pins fail and the motors then separate relative to each other and to the dart. The motors are

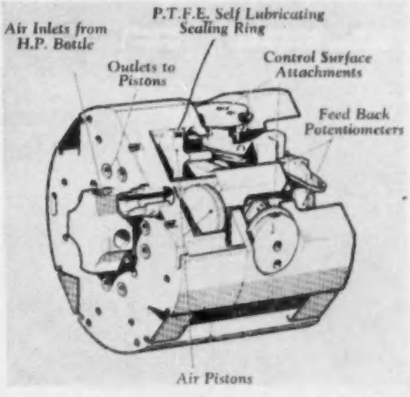


Fig. 8 Cut-away view of Fireflash pneumatic actuator. The four electro-pneumatic relay valves which are mounted on the forward face of the unit are not shown.

fitted with stabilising fins to prevent them toppling after separation and decelerating fast enough to endanger the firing aircraft.

Turning from the mechanical aspects of the missile, the control and guidance components mounted on the chassis comprise, from front to back: (i) A forged light-alloy air bottle containing air stored at 3,000 lb. per sq. in. to provide pneumatic supplies, an internal reducing valve (down to 100 lb. per sq. in.) and an electro-pneumatic stopcock; (ii) lateral accelerometers measuring in the two control planes; (iii) an air-driven gyro assembly, comprising a roll-displacement gyro and two rate gyros measuring in the two control planes, and provided with a very neat mechanism for caging the roll gyro from the outside. The gyros are continuously "blown" while the missiles are carried by the aircraft; during missile flight they coast. The rate gyros are fitted with a speed monitoring device; (iv) the "receiver" comprising several blocks of electronic components, predominantly interpreting received guidance signals but also containing the control-system electronic components; (v) the electrical power-supply unit; (vi) the servo motor comprising the actuator and its four pairs of piston-cylinder units, each pair independently operating one of the rudders in response to the commands of one of the four electro-pneumatic relay valves; and (vii) the aerial assembly.

The electrical sockets at the forward end of the air-bottle provide connections to the fuse and to the firing circuit, as well as to a telemetry transmitter which can be fitted in the warhead bay in non-explosive rounds.

All the components listed above have been designed and developed by the Fairey Aviation Company, although the manufacture of some of them has been subcontracted. In particular, the Plessey Company, Limited, has made a significant contribution in the production of receivers, as have E. K. Cole Limited with the radar beam set. The willing co-operation of aircraft contractors, among them Gloster, Armstrong-Whitworth, Hawker, Air Service Training and Vickers-Armstrongs (Supermarine), has expedited the installation of the weapon system in aircraft suitable for trials and operational use. The complete development programme has been conducted under Ministry of Supply contract, technical support being forthcoming from its establishments, the Royal Aircraft Establishment at Farnborough and at Westcott, the Royal Radar Establishment at Malvern, the Armament Research and Development Establishment at Fort Halstead and from its firing ranges.

VIBRATION-FREE HEAVY DUTY COMPRESSORS

Oil-Cooled High-Speed Rotary Vane-Type Machines

An important advance in the design of heavy industrial compressors is shown in the new Type OCR range oil-cooled high-speed rotary compressors announced by Worthington-Simpson Limited, Newark, which will be on view on the firm's stand at the Engineering, Marine, Welding, and Nuclear Energy Exhibition next week. In first cost these machines compete favourably with conventional reciprocating compressors designed for the same type of duty; in maintenance requirements, it is claimed, they completely outclass the reciprocating machine, having the minimum of moving parts and being cool-running and free from vibration; and their installation is simpler, since they require no heavy foundations, about half the floor space, considerably less height, and being much lighter are easier to handle.

Earlier types of dry-running vane-type rotary compressors have been limited to pressures of about 40 lb. per sq. in. owing to the difficulties of obtaining an effective seal between the cells and consequent overheating. In the Worthington-Simpson rotary vane-type compressor, these difficulties are overcome by injecting oil into the air to act as a sealing, lubricating and cooling medium during compression.

The type OCR oil-cooled rotary compressor is a two-stage single-shaft machine designed for operating pressures up to 125 lb. per sq. in., and running at 1,450 r.p.m. There are four basic units with capacities 200, 300, 450 and 600 cub. ft. per minute. These can be combined to form larger units of 900, 1,050 and 1,200 cub. ft. per min. by driving two units from a single double-ended motor. One of the reasons for the low installation costs of this type of compressor is their low starting-torque requirement—they are completely unloaded for starting—which makes it possible to use squirrel-cage motors and star-delta starting equipment.

The first- and second-stage compression cylinders are enclosed in a cylindrical welded-steel casing, the lower part of which forms an oil reservoir which is maintained at the air delivery pressure. Air enters the first stage through an oil-bath cleaner, which removes all dust, and then through a suction closure valve. Cooled oil is injected into the airstream through drilled passages in the rotor casing. From the first stage, the air, compressed to 30 lb. per sq. in., is fed to the second-stage cylinder, where again it receives a charge of cooled oil, and is further compressed to 100 lb. per sq. in. The delivery air, saturated with oil, passes through a port into the outer casing and thence to a first-stage separator chamber; from there it passes to the second stage of separation comprising two chambers containing coarse metallic filtering media, and finally through a series of thick felt pads, whence it passes to an air reservoir. The separated oil falls to the bottom of the compressor casing, from where it is transported, under the action of the air pressure in the casing, through a strainer and into a water-cooled oil cooler. From here, the oil flow divides, part being directed to the first-stage rotor casing and the remainder to the second stage.

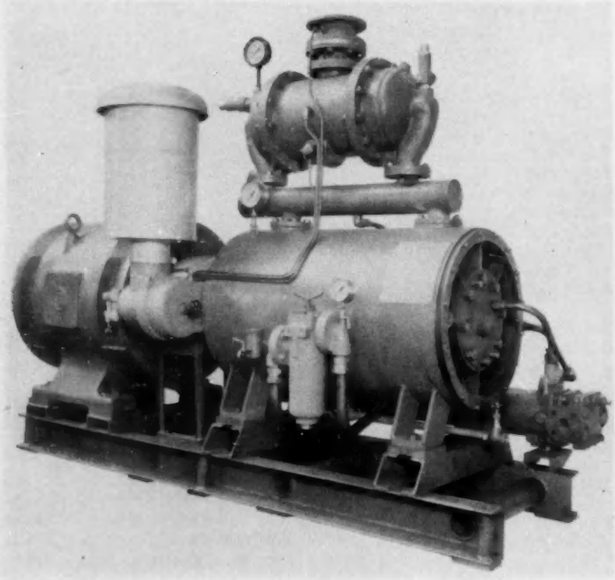
Normally the delivered air temperature is in the region of 170 to 175 deg. F., but should the temperature rise due to failure of the oil-cooler water supply, or through attempting to operate the machine with an empty oil reservoir, a thermostat cuts out the drive motor as soon as a temperature of 200 deg. F. is reached. Thus after-cooling is not essential and there is no possibility of carbon formation. The low operating temperature also makes for greater volumetric efficiency since the clearances can be kept small.

The only moving parts subject to wear are the vanes, which slide freely under centrifugal force, the ball bearing at the inlet end of the rotor shaft, and the two roller bearings at the low-pressure and high-pressure outlet ends. After much experimental work, non-metallic vanes have been selected rather than metallic ones. In current machines, plastics compression vanes are employed, and have proved to be most satisfactory in wearing qualities. These vanes are machined to close tolerances, as are also the slots in the forged-steel rotors. A Cincinnati milling machine has been acquired specially for this purpose. The cast-iron rotor casings also are highly finished and great care is taken during manufacture to ensure their complete cleanliness. The oil film lubrication, allied with plastics vanes, has proved most effective in preventing wear of the rotor cylinders.

Both rotors are on the same shaft, the first-stage rotor forging being integral with the shaft, and the second-stage rotor being free to slide axially on the shaft to allow for expansion. At the low-pressure end, the shaft is sealed by a pre-loaded mechanical seal, a well-known Worthington-Simpson product. All casing joints are sealed by means of O-rings, no jointing materials being employed in the compressor.

A suction and air-release valve off-loads the compressor when the air-receiver pressure exceeds a pre-set value—generally 100 lb. per sq. in. This valve incorporates a hand unloading control for starting. The valve also serves to release pressure automatically from the outer casing and from the rotor casing when the receiver-pressure unloads the machine. When the machine is standing idle, oil from the low-pressure stage may drain into the high-pressure cylinder. To prevent the possibility of hydraulic lock in this high-pressure cylinder, therefore, a patented valve automatically opens to relieve the oil build-up in the cells of the high-pressure rotor, allowing it to escape to the outer casing.

Largely as a result of the greatly-reduced maintenance burden, the rotary type of compressor is rapidly being adopted, notably by large organisations in the aircraft, steel-making, and automobile industries, who have been among the very first purchasers of the machines, particularly in the 600 size.



The type OCR two-stage oil-cooled rotary air compressor operates at pressures up to 125 lb. per sq. in. and is available in four basic units with capacities up to 600 cub. ft. per minute, which can be combined to form larger units up to 1,200 cub. ft. per minute.

ATOMIC REVIEW

Progress Report

THE reports submitted from time to time by the various bodies engaged in atomic energy work are usually rich in information. Such reports not only provide a broad indication of current progress, but also give details of technical discoveries made in the periods surveyed. Items from two reports made public within the last six weeks are reproduced below.

U.K.A.E.A.

As mentioned in Atomic Review on August 2, the United Kingdom Atomic Energy Authority have recently published their *Third Annual Report* (1956 to 1957). Many of its items have already been discussed in Atomic Review but certain of the following notes and others to be published in due course will be taken from that source. Among its most useful sections was a table of British experimental reactors, which is reproduced on this page.

U.K.A.E.A. Experimental Reactors

The table lists U.K.A.E.A. experimental reactors in operation or under construction at March 31, 1957, together with details of their construction, mode of operation and purpose. It should be emphasised that there are several other reactors, operating or projected, in Britain —the A.E.I. research reactor MERLIN, the Central Electricity Authority nuclear power stations under construction at Bradwell (Nuclear Power Plant Company, Limited) and Berkeley (A.E.I.—John Thompson Nuclear Company, Limited), and the station to be built for the South of Scotland Electricity Board at Hunterston (G.E.C.—Simon-Carves). The last three plants named will not, however, be experimental, but full-scale power stations.

Some of the more advanced systems previously listed under Stage 3 of the British programme (see Atomic Review, August 3, 1956) show greater potentialities for early development than others. Of the types referred to in the Second Annual Report as Stage 3 systems, work is continuing on all four, though at differing rates. A decision has been taken to build a high-temperature zero-energy critical assembly, and good progress continues to be made on the experimental fast reactor at Dounreay. The homogeneous aqueous and liquid-metal-fuelled systems will probably require much more research and development work before they are suitable for incorporation in a nuclear power programme.

Size and Rating of Gas-Cooled Reactors

The good neutron economy of the gas-cooled reactor has indicated that it should be feasible to re-design the reactor to make it suitable for smaller outputs of the order of 30 MW of electricity; the reactor size (even using natural uranium) and capital cost would be appreciably less than at Calder Hall. A feasibility study of such a plant is in progress. The rating of gas-cooled reactors could be improved by using hydrogen instead of carbon dioxide as coolant. The reaction of hydrogen with graphite and with fuel materials is being studied in BEPO.

Thermal Breeder with Ceramic Fuel

High priority is being given to the development of a thermal breeder reactor working on the uranium 233/thorium cycle and using a ceramic uncanned fuel able to withstand temperatures of the order of 800 deg. C. The fissile and fertile materials and a moderator are to be combined in a semi-homogeneous system; the heat developed will be transferred by high-pressure gas. The system offers promise of high ratings, high thermodynamic efficiencies, and low fuel costs. A reactor experiment is expected to come into operation by 1960; and the system is expected to be suitable for medium power stations and ship propulsion. A contract to build an experimental reactor using thorium is mentioned in the report.

Ceramic and Cermet Fuels

The trend in development of fuel elements for advanced reactors has been towards ceramic, rather than metallic, elements because the evidence now available indicates that ceramics may be more suitable for high-temperature operation. Thus uranium dioxide has been irradiated in the Chalk River reactor in conditions that resulted in the temperature at the centre of the fuel exceeding 2,000 deg. C.; nevertheless, the material kept its size and shape well. This fuel could be used in either gas-cooled or liquid-cooled reactors. A technique for manufacturing uranium dioxide, cheaper than the conventional one, has been developed which produces high-density specimens to accurate dimensions in a single operation.

Ceramics generally have the disadvantages that their resistance to sudden temperature changes and their heat conductivity are both low. These disadvantages are reduced in cermets, that is, dispersions of ceramic materials in a metal matrix. Cermets studied have included uranium dioxide in aluminium and in steel.

Beryllium Canning

The techniques for canning fuel elements in beryllium have been refined and consolidated. A number of beryllium-canned fuel elements have been fabricated and tested out-of-pile, and some are now undergoing in-pile tests.

Control Rods and Helium Build-up

Some of the neutron-absorbing materials used in reactor control rods form helium when they absorb neutrons. It has become apparent that the accumulation of this gas in the material may have an effect similar to, and as serious as, the corresponding effect in fuel elements of accumulating fission-product gases. The problem is particularly acute in high-flux reactors. It has therefore been decided to undertake a general survey of control materials and an experimental investigation of methods for improving them. As one possibility, cermets of boron carbide and

Experimental Reactors at Harwell

Name	Date of start-up	Peak neutron flux	Maximum heat output	Moderator	Coolant	Fuel	Purpose
1. GLEEP ..	1947	$3{\cdot}7\times10^{10}$ (thermal) neutrons per sq. cm. per sec.	100 kW	Graphite	Air	Natural uranium metal and oxide	Initially isotope production and general neutron physics. Now routine graphite, uranium quality testing; research with oscillator; biological irradiations.
2. BEPO	1948	2×10^{12}	6 MW	Graphite	Air	Natural uranium	Isotope production and general radiation source.
3. ZEPHYR ..	1954	8×10^{8} (fast)	A few watts	None	None	Plutonium	Fast reactor studies.
4. DIMPLE ..	1954	About 10^{5}	100 watts	Heavy water	None	Varies	Thermal reactor studies
5. ZEUS ..	1955	5×10^{9} (fast)	100 watts	None	None	Uranium 235	To study a particular core design for Dounreay fast reactor.
6. ZETR ..	1955	4×10^{5}	Negligible	Heavy or light water	None	Uranium 233, 235 or plutonium	To study physics of homogeneous aqueous systems.
7. LIDO ..	1956	10^{12}	100 kW	Natural water	Natural water	Uranium 235	Thermal reactor studies, including shielding
8. DIDO ..	1956	10^{14}	10 MW	Heavy water	Heavy water	Uranium 235	Isotope production, neutron physics, radiation chemistry, nuclear reactor material studies.
9. NERO ..	1957	About 10^{8}	Less than 100 watts	Graphite	None	Slightly enriched uranium	Investigations for advanced graphite-moderated reactors.

Experimental Reactors under Construction

Name	Location	Date of start-up	Peak neutron flux	Maximum heat output	Moderator	Coolant	Fuel	Purpose
10. Fast Reactor, Dounreay	Dounreay, Caithness	1958	—	60 MW	None	Liquid metal	Enriched uranium or plutonium	Fast reactor breeding studies.
11. PLUTO	Harwell ..	1957	10^{14}	10 MW	Heavy water	Heavy water	Highly enriched uranium	Studies on nuclear reactor materials.
12. DMTR (Pluto type)	Dounreay, Caithness	1957	10^{14}	10 MW	Heavy water	Heavy water	Highly enriched uranium	Studies on nuclear reactor materials.
Plutonium Producing Reactors in Production								
13/14. Windscale (2 reactors)	Cumberland	1950	—	n.a.	Graphite	Air	Natural uranium	Plutonium production.
Power/Plutonium Producing Reactors in Production (1)								
15/16. Calder "A" (2 reactors)	Cumberland	1956	—	180 MW(2) per reactor	Graphite	Carbon dioxide	Natural uranium	Power and plutonium production.
Power/Plutonium Producing Reactors under Construction (1)								
17/18. Calder "B" (2 reactors)	Cumberland	1958 (1st reactor)	—	180 MW(2) per reactor	Graphite	Carbon dioxide	Natural uranium	Power and plutonium production.
19/22. Chapelcross (2 stations, "A" and "B," 4 reactors)	Annan, Dumfriesshire	1959 (3 reactors)	—	180 MW per reactor	Graphite	Carbon dioxide	Natural uranium	Power and plutonium production.

1. All power stations operated, or under construction for future operation by the Authority, are "two reactor" stations. These are Calder Hall "A," Calder Hall "B," Chapelcross "A" and Chapelcross "B."

2. Total output for Calder "A" (2 reactors) is 92 MW (electrical), of which 65 MW is supplied to the C.E.A. grid. When both Calder stations "A" and "B" (2 reactors each) are in operation, the total output will be 184 MW (electrical) and the feed-back percentage from each reactor will be slightly reduced, so that the combined output to the C.E.A. grid from both Calder stations (4 reactors) will be 150 MW. The electrical output from Chapelcross "A" and "B" stations will be identical in all respects with Calder "A" and "B."

Fig. 1 Inserting a fission chamber into the graphite moderator stack of the Harwell low-energy experimental reactor NERO. The reactor is so designed that the moderator blocks can be re-arranged to give a variety of lattice pitches.

steel have been made and are being tested. Alternative materials are alloys (including ternary alloys) of silver and cadmium, several of which have been fabricated and tested.

The Authority's Research and Development Branch have brought into operation a plant for separating boron 10 from natural boron. This isotope, which absorbs neutrons intermediate in energy between fast and thermal reasonably well, is used in control rods.

Sodium Graphite Studies

One of the Authority's reactors, NERO, which was discussed in Atomic Review for March 15, is shown in Fig. 1. It is an experimental low-energy reactor built at Harwell to investigate the physics design problems associated with the more advanced kinds of graphite-moderated reactor (such as those cooled by liquid sodium) and to check calculations concerning the effect of separating the fissile and fertile constituents of a nuclear fuel. Such calculations would be important in the design of reactors in which nuclear fuels such as plutonium may be re-cycled. NERO first went critical last February 23. In the illustration an engineer is seen inserting a fission chamber into the reactor graphite moderator stack. The shape of the moderator blocks are such that the reactor can be quickly dismantled and rebuilt to give a variety of lattice pitches.

Hot liquid sodium attacks graphite, so the two must be separated by a metal of low neutron absorption such as zirconium. The compatibility of hot liquid sodium with zirconium and other metals of the reactor is being studied in test rigs by the Authority. Experiments have shown that it is essential to keep the oxygen content of the sodium down to a few parts per million. In a liquid-metal cooled reactor some fuel enrichment will be necessary, owing to poorer neutron economy than in a gas-cooled reactor. Fuel costs will thus be higher and there is therefore some doubt as to the value of developing this system.

Making Heavy Water

Research into methods of manufacturing heavy water has been concentrated on the hydrogen-distillation and the dual-temperature chemical-exchange processes. In the first of these, hydrogen gas is cooled to its liquefaction temperature of — 253 deg. C. and then distilled in a column, when the heavy hydrogen (deuterium) is separated from the light. An engineering design study of the process has been undertaken in collaboration with a firm of consultants, and experimental work done on the development of reversing heat exchangers. A closed cycle form of the process is also being developed in which the stripped (light) hydrogen from the distillation unit is brought into contact with natural water, from which it picks up more deuterium by chemical exchange; this enriched hydrogen is then fed through the separation process.

A theoretical design study of the dual-temperature chemical exchange process between sulphuretted hydrogen gas and water is nearing completion, and a new method of heat recovery has been developed which makes the process more attractive for operation in this country. A new form of the exchange process between liquid ammonia and hydrogen is also being studied.

Physics of Solids

One field of fundamental research which has been greatly affected by the development of nuclear reactors is the study of the physics of solids. Reactors provide a quite new and complex environment for solids, the effects of which are as important for a fundamental understanding of the properties of solids as for the technology of atomic energy. Studies at Harwell have enabled the behaviour of graphite under neutron irradiation to be deduced from a knowledge of its crystal structure, and have led to a successful correlation between neutron-induced damage and changes in the electrical properties of the graphite. Experiments have also been carried out on the growth of graphite under irradiation and the storage of energy which occurs due to the displacement of atoms.

Reactors have also made practicable a valuable new technique for solid state studies called neutron diffraction, in which beams of neutrons are used to explore the atomic architecture of solids; this work has ranged from a study of the shapes of molecules in organic chemicals to a search for a fuller understanding of the nature of magnetism in metals and alloys. This reactor-inspired work is backed by general theoretical studies based upon the application of the methods of theoretical chemistry to solids regarded as very large molecules.

Neutron Detection and Mesonic Atoms

Some time ago nuclear physicists developed, initially for cosmic ray work, a precision proportional counter, filled with helium 3, which was a great advance in detectors for neutrons in the medium energy range. The counters have more recently been used to study the radiation emitted by mesonic atoms, that is, atoms in which the electron in the innermost energy level is replaced by a negative π-meson. Mesonic atoms created considerable interest a short time ago as a means of achieving the fusion of hydrogen and deuterium atoms without the use of high temperatures (see Atomic Review last January 11). The counters have also been used to measure neutron spectra in the reflector of a fast reactor and to study certain energy levels of the uranium 238 nucleus about which surprisingly little was known.

U.S.A.E.C.

The United States Atomic Energy Commission has made public its twenty-second semi-annual report to the United States Congress. Certain items from the report concerning activities of the Argonne National Laboratory are referred to in the following notes.

EBWR

The performance of the Experimental Boiling Water Reactor (EBWR) at Argonne indicated that it can probably produce satisfactorily twice the design reactor power of 20 MW (heat). A further increase in power may be achieved, principally by forced circulation of the coolant. Future operating plans call for substituting heavy water for the light water now used as the reactor's coolant and moderator. (See Atomic Review, February 1 and May 17 this year.)

Borax Four

Power excursion tests, also carried out by A.N.L., were started in January with the boiling water reactor, BORAX IV, at the National Reactor Testing Station, Idaho. Steady-state boiling tests at atmospheric pressure were carried out during February with power levels as high as 2·6 MW. Oscillations in reactivity levels were evident at higher power, but the general evidence indicated that the reactor was much more stable than anticipated. BORAX IV is a modification of the previous reactor, designated BORAX III, accomplished by substituting aluminium-clad uranium oxide thorium oxide fuel elements. Its principal purpose is to test the stability and safety of such fuels. The original BORAX III core assembly is illustrated in Fig. 2.

Decomposition of Boiling Water

Operational experience with Argonne National Laboratory's BORAX-III power plant at the National Reactor Testing Station in Idaho demonstrated that the rate of decomposition of water into hydrogen and oxygen is appreciable under boiling-water conditions. Low, but corrosive, levels of oxygen appear in the effluent steam, in marked contrast to the radiation stability of water in non-boiling water moderated reactors. Laboratory experiments at Argonne carried out with cobalt 60 gamma rays confirmed the BORAX-III tests. During boiling both hydrogen and oxygen were stripped from the irradiated water, hydrogen more readily than oxygen. The yields of hydrogen and oxygen observed in the laboratory were about equal to the BORAX III yields and equivalent to the primary gamma ray decomposition of water into hydrogen and hydrogen peroxide. Recombination of these products by the nascent hydrogen atoms and free hydroxyl radicals, effective in preventing decomposition of water in conventional reactors, was not as significant in irradiated boiling water. Since two- to three-fold greater primary water decomposition was found for recoil protons than for cobalt 60 gamma rays, and since the recoil proton energy liberated in BORAX III is about 50 per cent. of the total ionising energy,

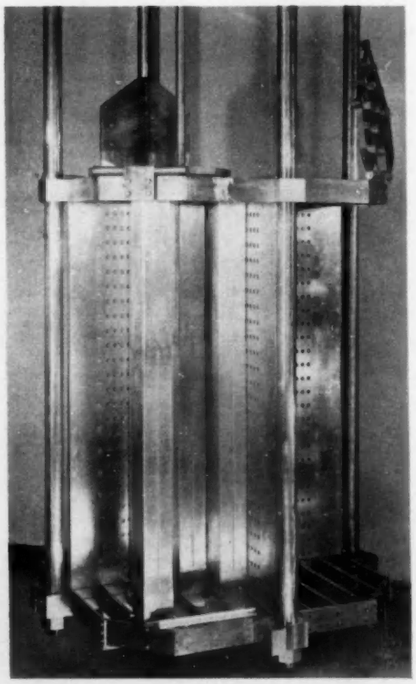


Fig. 2 Core assembly of the experimental boiling-water reactor BORAX III operated by Argonne National Laboratory, U.S.A. New fuel elements of aluminium-clad uranium oxide and thorium oxide have now been substituted and the reactor designated BORAX IV.

an even greater water decomposition yield might be expected in the boiling-water reactor. The lower experimental yield indicated that about half the liberated hydrogen and hydrogen peroxide recombined under operating conditions of BORAX III.

Liquid Metal Slurries

The investigation of suspensions (slurries) of fissile materials in liquid sodium-potassium alloy was continued at Argonne National Laboratory with the aim of developing a fluid reactor fuel which might find application in both fast power breeder reactors and moderated reactors. It was demonstrated that the pure compound uranium dioxide is wetted by sodium-potassium alloy at room temperature (a desirable characteristic, pointing to mechanical stability of the suspension) and could be circulated in a loop at a concentration of 10 per cent. by volume of uranium dioxide. Two small loops have been operated up to 600 degrees centigrade and, within the limits of the chemical detection techniques, no erosion or corrosion of the stainless-steel loops occurred.

In the first high-temperature loop, the uranium dioxide dropped out of suspension when the temperature rose above 500 deg. C. but immediately re-suspended when the temperature dropped below 500 deg. C. This effect was eliminated in the second loop by adding powdered uranium (1·5 per cent. by weight of the uranium dioxide) with the uranium dioxide. The cause of the uranium dioxide dropping out of suspension and the reason for the effectiveness of the uranium metal in preventing this are still under investigation. It was also observed in these loop experiments that very little change in particle size occurred. An in-pile loop experiment was planned to investigate the stability of the uranium dioxide slurry under irradiation. If fission products have no deleterious effect on the stability or rheology of the slurry, then the composition investigated to date could probably be used as fuel in enriched thermal reactors. Other compounds being studied as slurry fuel possibilities are the uranium silicides (U_3Si) and (USi_2).

Volatility Processing

Considerable progress was made on the volatility process development studies under way at the Argonne and Oak Ridge National Laboratories. The Argonne National Laboratory demonstrated on pilot-plant scale that single-cycle volatility processing will decontaminate irradiated natural uranium sufficiently so that the residual radioactivity is less than that of unirradiated natural uranium. Investigations continued on a volatility process for separating plutonium from fission-product residues. Construction of the Oak Ridge volatility pilot plant involving a different processing approach was essentially completed.

Pyrometallurgical Separation

Atomics International and Argonne National Laboratory continued cold preparatory work on pyrometallurgical processes for re-cycling fuels from the Sodium Reactor Experiment and the Experimental Breeder Reactor No. 2. Argonne worked on a process for separating and purifying irradiated uranium by dissolving fuel in molten zinc, followed by the formation and separation of an intermetallic uranium-zinc compound. Preliminary results indicated that this process for limited decontamination may be suitable for use in integrated facilities which contain an operating reactor, a chemical processing plant, and facilities for remote fuel-element refabrication. A possible advantage was that this process may permit the separating of certain fission products which most pyrometallurgical methods do not remove; that is those elements less electro-positive than uranium.

Fluidised Bed Calcination

The calcination treatment of chemical reprocessing plant waste materials was successfully demonstrated on a cold pilot-plant basis by Phillips Petroleum. Runs planned to reach one-tenth of full level radioactivity on Idaho chemical processing plant wastes were under way at Argonne National Laboratory. Work along similar lines was carried out also at Brookhaven National Laboratory. Successful demonstration of the feasibility of calcining highly radioactive wastes would be a significant preliminary step toward ultimate disposal.

Proton Synchrotron

Argonne National Laboratory continued studies on the design of a 12·5 GeV proton synchrotron, able to produce all present known sub-nuclear particles. The magnet will be of the weak-focusing variety, with a guide field about 50 per cent. stronger than those used currently in other synchrotrons. As a result, a very substantial saving of iron can be effected as well as a reduction in the size and cost of the magnet shelter. Studies indicate that it will be possible to build this accelerator magnet more easily and rapidly than any other magnet of the weak-focusing variety. The output of protons from this accelerator would be expected to be an order of magnitude greater than that of any other existing accelerator in this energy range. Detailed theoretical analyses of the orbit stability problems have been carried out in order to arrive at appropriate parameters.

Emitters of Delayed Neutrons

At the Argonne National Laboratory a method was developed using a continuous flow of gas to make a very rapid chemical separation of either of the halogens, bromine or iodine, from other fission products of uranium 235 produced by irradiation with thermal neutrons. The method made possible the identification of certain emitters of delayed neutrons formed from halogen fission products which have a short half-life. As in all other delayed-neutron events, the half-life is the period required for the beta decay of the nuclide's immediate radioactive ancestor, the neutron being emitted at once after the formation by this process of the unstable neutron-emitting nuclide. Two hitherto unrecognized delayed-neutron emitters were found in the experiment. One is krypton 88, formed by the beta decay of bromine 88 with a half-life of 15·5 sec. The other is xenon 138, formed from iodine 138 that decays with a half-life of 5·9 sec. Krypton 88 and xenon 138 are the first nuclides with both even atomic number and even neutron number, formed in this way, that have been found to be unstable neutron emitters. A study of the mass-energy relations in these reactions indicated that such even atomic number-even neutron number nuclides are, however, as likely to be neutron emitters as are the even atomic number-odd neutron number nuclides previously identified.

General Notes

Fourth C.E.A. Nuclear Power Station

The Central Electricity Authority propose to make early application to the Minister of Power and the local planning authority for consent to develop their fourth nuclear power station at Trawsfynydd, Merionethshire. The Authority have reached the conclusion that a suitable site for nuclear power generation in North Wales exists also at Edern in Caernarvonshire. The Trawsfynydd site is on the northern shore of the artificial lake of that name which was created some thirty years ago to serve as the storage reservoir for the Maentwrog hydro-electric power station. This lake is large enough to provide cooling water for a nuclear power station of up to 500 MW capacity. The land, which is owned by the Authority, is rocky and broken and of no agricultural value. Reactors can be founded direct on rock. The proposal for Trawsfynydd will be a station of 400 to 500 MW output capacity, to be brought into service in 1962, and connected by overhead line to the 275 kV transmission system at the Ffestiniog pumped storage station now under construction some five miles to the north. Reference to the pumped storage station was made in Atomic Review last April 5.

The Edern site is some two miles west of the village of that name and is on the northern coast of the Lleyn Peninsula. It consists mainly of rough heathland and low cliffs. After excavation the reactors could be founded directly on rock. This site is suitable for a larger development than Traswfynydd, as unlimited cooling water is available from the sea.

United Kingdom and Norway Collaborate

The United Kingdom Atomic Energy Authority and the Norwegian Institute for Atomic Energy have recently signed an agreement for co-operation in connection with the Norwegian Halden Reactor Project. This agreement is the result of the discussions mentioned in the exchange of Notes between the United Kingdom and the Norwegian Governments which has been published as a White Paper (H.M.S.O.—Cmmd. 245). This project is concerned with an experimental reactor, scheduled to start operation early in 1958, which is designed to produce process steam suitable for wood-pulp mills and other industrial uses. The Authority have undertaken to supply the initial charge of uranium fuel elements for the reactor. The Institute and the Authority will also co-operate in a research programme with a view to developing suitable fuel elements for later charges for the reactor. The Agreement provides for the Authority to have access to the reactor design and to the operating experience obtained from this important experiment.

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NOTICES OF MEETINGS

Incorporated Plant Engineers

LONDON
"Maximum Demand and the Power Factor, and Their Effect on the Electricity Tariff," by T. A. Williams. London Branch. Royal Society of Arts, John Adam-street, Adelphi, W.C.2. Tues., Sept. 3, 7 p.m.*

CHESTER
"The Cost Accountant and the Plant Engineer," by R. G. Hall and B. J. Willson. Mersey and North Wales Branch. The Blossoms, City-road, Chester. Mon., Sept. 9, 7.15 p.m.

DUNDEE
Discussion on "Variable Speed Drives with Voltage Regulation Equipment." Dundee Branch. Mather's Hotel, Dundee. Mon., Sept. 9, 7.30 p.m.

EDINBURGH
Open Meeting. Edinburgh Branch. 25 Charlotte-square, Edinburgh. Tues., Sept. 3, 7 p.m.

LEICESTER
"The Painting of Buildings," by R. Woodwards. Leicester Branch. Bell Hotel, Leicester. Wed., Sept. 4, 7 p.m.

Institute of Petroleum

LONDON
"Some Developments in Marine Drilling Foundations," by A. Kranendonk. Wed., Sept. 4, 5.30 p.m.*

Institution of Engineering Designers

NEWCASTLE-UPON-TYNE
Chairman's Address, by J. Teasdale; and an informal discussion on "Branch Affairs." North-East Branch. Northern Architectural Association's Hall, 6 Higham-place, Newcastle-upon-Tyne. Mon., Sept. 9, 7.15 p.m.

Institution of Production Engineers

COVENTRY
"Changing from Batch to Flow Production," by H. C. Blackford. Coventry Graduate Section. At works of the British Piston Ring Co., Ltd., Holbrook-lane, Coventry. Wed., Sept. 4, 7.15 p.m.

Royal Aeronautical Society

LONDON
45th Wilbur Wright Memorial Lecture on "Advanced Education and Academic Research in Aeronautics," by Dr. Clark B. Millikan (of the Guggenheim Aeronautical Laboratory, California Institute of Technology). Institution of Civil Engineers, Great George-street, S.W.1. Fri., Sept. 13, 6 p.m.

The address and telephone number of the headquarters of each institution are given below. Meetings in the headquarters town are held there unless otherwise stated. Particulars for this column should reach the Editor not later than Monday morning in the week preceding the date of the meeting.

* An asterisk is placed where it understood that tea is available prior to the time stated.

Incorporated Plant Engineers, 12 The Parade, Solihull, Warwickshire. (Solihull 1111).
Institute of Petroleum, Manson House, 26 Portland-place, London W.1. (LANgham 2250.)
Institution of Engineering Designers, 38 Portland-place, London, W.1. (LANgham 8847.)
Institution of Production Engineers, 10 Chesterfield-street, London, W.1. (GROsvenor 5254.)
Royal Aeronautical Society, 4 Hamilton-place, London, W.1. (GROsvenor 3515.)

THE HUMAN ELEMENT

ABC of Salesmanship

The qualities required of a salesman, and the way to develop them, are discussed in a new publication by the British Institute of Management, entitled *Sales Training in Industry* (5*s*.). This is the report of a study group who have examined existing training facilities. They found that courses for the training of salesmen were " unfortunately few in number " and concluded that more should be started. These courses, says the report, " serve a useful purpose in teaching novices the ABC of salesmanship. Usually they aim at creating the right climate in which a salesman can feel at home and develop. For salesmanship is not merely a question of skill, it is also a matter of mental attitude and most of these courses aim at developing this."

The experience of eleven companies was represented in the group, whose chairman was the managing director of Dictograph Telephones, Mr. George La Niece. Engineering industries were well represented, and there was no question of the group having ignored the special problems of industries selling capital goods. For this reason the findings are of particular significance, and in line with views frequently stated in ENGINEERING: " It is not enough for salesmen alone to be trained. Everybody who comes into contact with customers should be considered as a possible subject for training." "All training should be based on a formal analysis of the work to be done by the sales force. It is not sufficient for policy to be based on what the sales manager considers to be needed or what has been done in past years." " The need for training is continuous. Salesmen must be kept abreast of the latest developments in their fields."

Salesmanship, whether of vacuum cleaners or steam turbines, can be taught. A company manufacturing weighing equipment " looks for the three T's when selecting salesmen—toughness, tenacity and tact." The three R's are not less necessary, but above all the salesman needs an honest approach, the ability to listen and an unshakable enthusiasm for the product and the firm.

Unions' Warning to Labour

Important changes of positions are taking place in the Labour movement. The right wing and the moderate among trade union leaders are moving to the left. The shift, imperceptible when it first began after the death of Mr. Bevin, has gathered momentum and taken a more definite direction during the past year. The change of leadership in the Transport and General Workers' Union and the growing militancy of the leadership in the Confederation of Shipbuilding and Engineering Unions are striking examples of the shift to the left. The part played by traditionally moderate leaders in backing and even organising strike action is evidence enough of the new mood.

When Mr. Bevin was fighting the union's block votes during his abortive attempts to secure election to the Labour Party treasurership he did not find it hard to show up the yawning gap between union leaders and their rank and file. That the gap still exists even in the T. and G.W.U. was shown by the hot reception given to the militant Mr. Cousins by the Covent Garden strikers. But it is narrowing, as it had to if the leaders were to remain at the head. Increasingly now, criticisms of the Parliamentary Labour Party will come from the union side of the movement.

The president of the Confederation, Mr. H. G. Brotherton, made clear the shipbuilding and engineering unions' attitude in his opening speech to the Confederation's annual conference in Hastings. Many trade unionists, he said, expected the Labour Party to take considerable political risks to eliminate private ownership of the means of production. But Labour members of Parliament had a vested interest in the return of a Labour Government and their continuance in office. (Did he imply that the trade unions had not?) This would lead to an unconscious tendency to avoid decisions which might endanger their political lives, and to easy conversion to proposals designed primarily to obtain the support of a doubtful electorate. The warning was plain enough. Unless it is heeded during the next few months the unions' block votes at Party conferences may well force the issue. Fundamentally, the real cause of differences is the lack of a clear-cut Party policy. And it is difficult to envisage such a policy emerging from the present confusion.

Comparing Real Incomes

The fear that major differences in wage levels between the different countries in Western Europe will make the establishment of a free trade area a painful business for those with a relatively high standard of living has been expressed by trade unionists as well as employers. But there is so far a lack of precise knowledge, which makes comparison difficult. Until real incomes can be measured with reasonable accuracy, passionate arguments are likely to arise and prevent rational solutions. The work done in this field by the European Coal and Steel Community is therefore of considerable interest.

The High Authority has just published a leaflet entitled " Real Incomes of Workers in the Community " which makes an important contribution to existing knowledge on the subject. In particular, the definition of the methods used is useful, since a common approach is essential to obtain worthwhile comparisons. Comparisons of net incomes in 1956 of workers in the coal, iron ore, and steel industries in the six member countries show that if the problem is tackled intelligently reasonably good results can be obtained.

But, the report warns, " in a matter so difficult as the international comparison of real incomes we cannot, of course, expect to find an immediate and complete explanation of the differences that exist between one country and another." But the findings are of great interest: in 1956 the " real earnings per hour " in the steel industry in Luxembourg were precisely double those in Italy, and in Germany were lower than in Luxembourg, Belgium and Netherlands. A similar study for the engineering industries is urgently called for.

How Big is the Market?

Forecasting population trends is an essential function of planners, whether they are concerned with a nation's policy in respect of land use or with investment in steel-making or with the size distribution of a range of clothing. Practically all we do is affected by the number who do it. In 1800, Malthus thought that the rise in population would wreck mankind but he erred in regarding resources as fixed and not, as they have proved to be, largely a function of changing technology. During the past few years in Europe the main threat to prosperity has been insufficient numbers of people fit to work. Many influential economists construe a diminishing population as a greater threat to the living standards of the individual than an expanding one.

The Swedish economist, Gunnar Myrdal, believes that a growing market, based on a growing population, is the basic condition of a free unregulated capitalist system. A declining population is an ageing one, and as such suffers a loss of vigour and opportunity. But others, such as Professor Joseph Spengler of Duke University, North Carolina, argue that rising numbers dissipate resources and make it more difficult to invest in schemes likely to raise output and income per capital. And there are shades of opinion in between.

The major confusion exists in estimating population changes. In a review of three major works on the subject published recently in the United States, *Business Week* points out that forecasters " can get any estimate of world population they like—from 4,000 million to a ' conservative ' 7,000 million 100 years from now—depending on the assumptions they make." The only agreement is that there will be growth. Most of the experts foresee a vast increase in numbers but the assumptions they make, and their reasoning, are of greater interest than the resultant figures.

Improving the Civil Servant

The Treasury are accused of hostility towards the technical Civil Servant. Mr. Stanley Mayne, general secretary to the Institution of Professional Civil Servants, pulls no punches in his attack on the Treasury's attitude to the training of Government officers in scientific and technical subjects. Writing in the August issue of *State Service*, Mr. Mayne comments that " the Treasury is incredible in the way it seems deliberately to set out to defeat Government policy in relation to sandwich courses."

The object of Mr. Mayne's broadside is the delays that have occurred in reviewing the decision taken a year ago to bar Civil Servants, other than those engaged in either engineering or physics, from applying for sandwich courses. The matter is still under " careful consideration " only a few weeks away from the start of a new academic year. Also, Mr. Mayne says, the Treasury is decidedly pinch-penny in its attitude to pay and allowances for married men with domestic responsibilities. But so far the " hostile " attitude of the Treasury has led to delay and procrastination rather than adverse decisions. There is yet hope for chemists and others who are not engaged in engineering or physics. Science and engineering are advancing at such a high rate to-day that we cannot afford to allow education to cease on leaving school. Civil Servants, more than most, need to keep abreast of the latest developments.

Printers' Hitch

The proposed amalgamation between NATSOPA (the National Society of Operative Printers and Assistants) and the paperworkers' union has come up against a major difficulty. It is over finance, and may wreck the whole scheme. The proposals for a joint executive and a joint financial system are opposed by the paperworkers, whose branches have considerable independence from headquarters and a large measure of financial autonomy. NATSOPA, being more centralised, are unlikely to view the proposals as anything much more difficult than an extension of their own system.

The matter has been referred back to the paperworkers who will review the position at a special executive meeting next month. There will then be a ballot of members to decide whether or not the negotiators should be given fresh powers. This is the almost inevitable result of clashing traditions. The difficulties which will face the craft unions, all of which are old-established and self-contained, in their own negotiations over amalgamation will be even greater. The path to unity in the printing world, however sensible it may be, is still filled with obstacles. Not only good will but positive enthusiasm will be required to clear the way.

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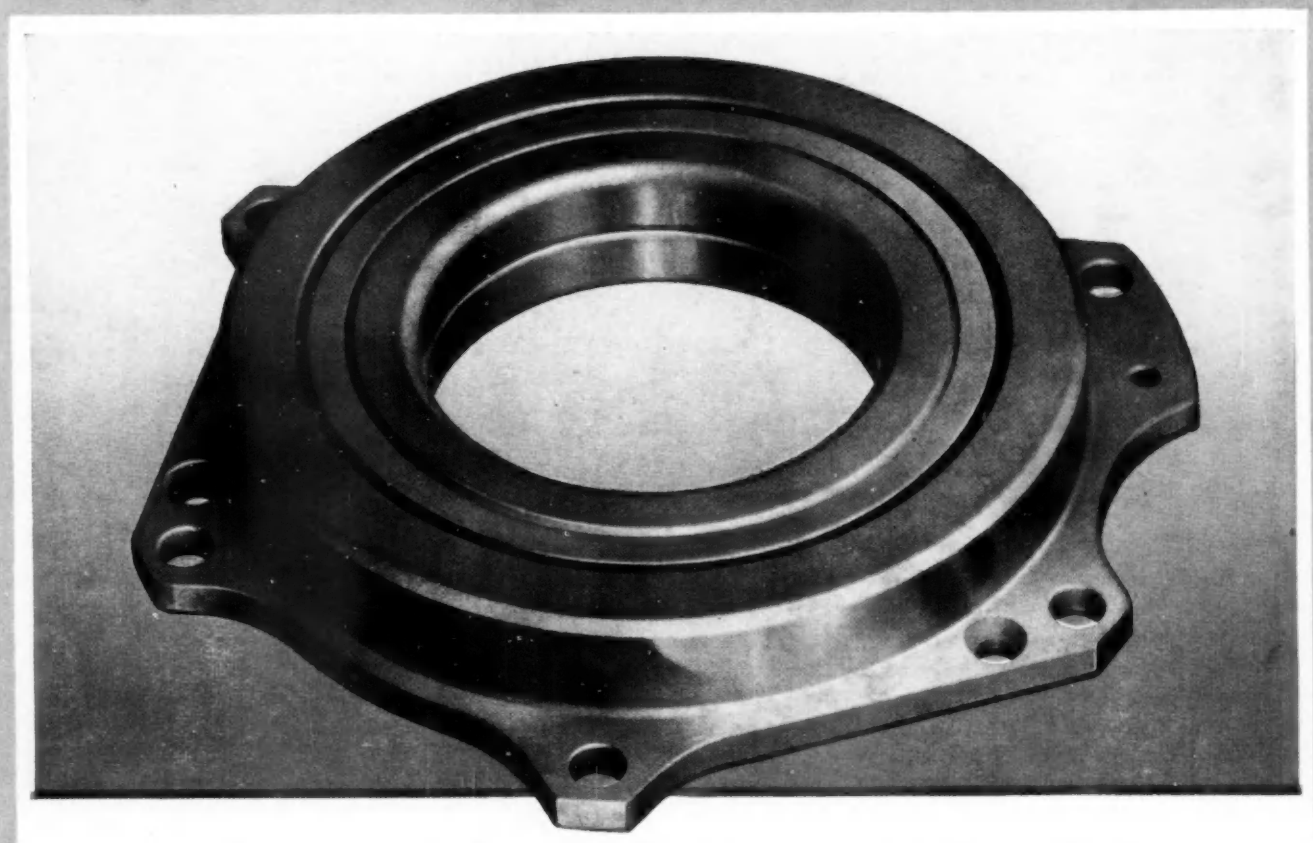

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